DISPLAY COPY

Longline Fishing for Tuna in the Central Equatorial Pacific, 1954

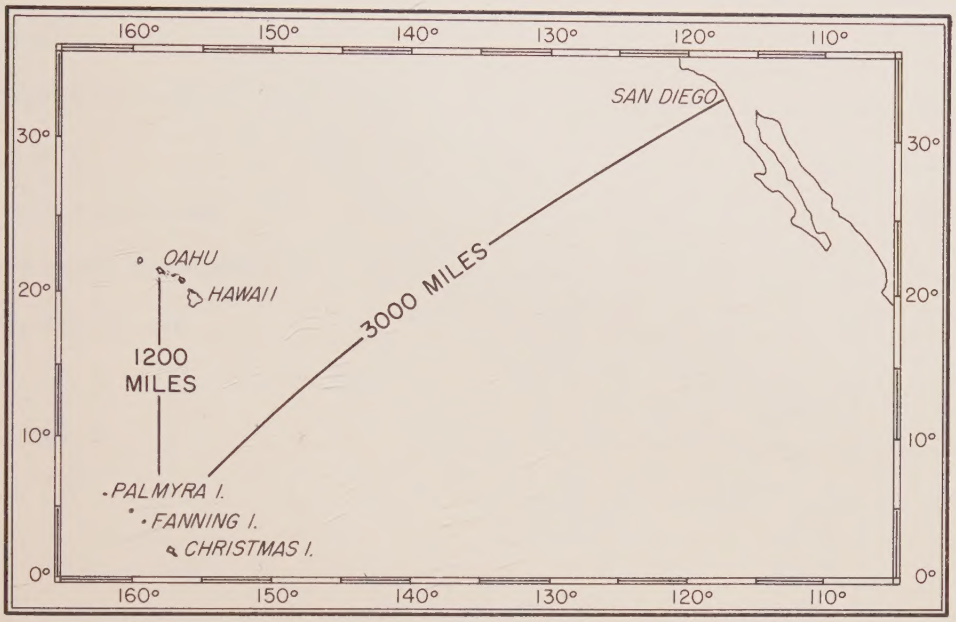
SPECIAL SCIENTIFIC REPORT – FISHERIES NO. 184

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

Explanatory Note

The series embodies results of investigations, usually of restricted scope, intended to aid or direct management or utilization practices and as guides for administrative or legislative action. It is issued in limited quantities for the official use of Federal, State or cooperating Agencies and in processed form for economy and to avoid delay in publication.

United States Department of the Interior, Fred A. Seaton, Secretary
Fish and Wildlife Service, John L. Farley, Director



LONGLINE FISHING FOR TUNA IN THE CENTRAL EQUATORIAL PACIFIC, 1954

By

Edwin S. Iversen, Fishery Research Biologist

and

Howard O. Yoshida, Fishery Aid
Pacific Oceanic Fishery Investigations
Honolulu, T. H.

Special Scientific Report--Fisheries No. 184

WASHINGTON: August 1956

Digitized by the Internet Archive
in 2026

https://archive.org/details/noaa-technical-report-nmfs-ssrf_1956-08_184_1

CONTENTS

	Page
Acknowledgments	1
Methods of collection and analysis of data	2
Vessel efficiency	3
Yellowfin abundance	3
Latitudinal variation	3
Longitudinal variation	4
Line Islands	5
Yellowfin catch composition	8
Observations on the environment	9
Sharks and shark damage	10
Summary	10
Literature cited	10
Appendix	11

LONGLINE FISHING FOR TUNA IN THE CENTRAL EQUATORIAL PACIFIC, 1954

By

Edwin S. Iversen, Fishery Research Biologist

and

Howard O. Yoshida, Fishery Aid
Pacific Oceanic Fishery Investigations
Honolulu, T. H.

One of the chief goals of the Pacific Oceanic Fishery Investigations (POFI) is to evaluate the equatorial Pacific tuna resources and to make the results of this appraisal available to American fishermen. In order to locate the regions of greatest tuna abundance and define their boundaries it has been necessary to do experimental fishing throughout vast areas of the equatorial Pacific. Our principal sampling tool has been the longline, which is used commercially to great advantage by the Japanese. Our research program has also of necessity included an evaluation of the longline method and of means of increasing its efficiency.

The present report is the fifth in a series and includes information obtained during experimental and commercial operations in the equatorial area in 1954. The earlier reports (Murphy and Shomura 1953a, 1953b, 1955, and Shomura and Murphy 1955) included processed data from cruises of 1950 through 1953, with some information from Japanese commercial fishing operations. The highlights of the 1954 fishing are:

(1) First commercial effort by American fishermen based on POFI research.

(2) First use of steel-mainline gear.

(3) Continued fishing for nearly 1 year in the Line Islands area, mainly near Christmas Island.

(4) Sharp difference in seasonal catch rates from previous years.

Longline catch statistics for the central equatorial Pacific during 1954 came from many sources. There were 2 POFI research cruises and 11 fishing trips by 6 American commercial vessels to the central equatorial region during the year. The John R. Manning (cruise 20) operated entirely within the Line Islands area; the Charles H. Gilbert (cruise 15) fished three north-south lines of stations, one close to Baja California at 119°W. longitude, one that crossed the Equator on 110°W. longitude, and a third which crossed the Equator on 155°W. longitude. The American commercial vessels operated in the vicinity of the Line Islands. Two of the commercial cruises made during 1954 were of immediate interest to the fishing industry so a general account of the venture was published (Iversen and Murphy 1955). In addition, longline fishing was initiated at American Samoa. The overall operation from January to April 1954 was reported by Van Campen (1954); the catch rates will be discussed in this report. Lastly, we have utilized the available data from Japanese longline fishing near the Equator.

In order to avoid needless repetition the present report does not include as detailed an analysis of the 1954 fishing results as was presented for the years 1950 through 1953 in the four previous numbers of the series. For instance, little space will be devoted in this report to the discussion of tuna other than yellowfin since other species were not taken in sufficient quantity to be of commercial interest. Operational details and the complete catch records for fishing cruises during 1954 are given in the Appendix. For the sake of simplicity, only the vernacular names of the various species in the catch will be used in this report. The scientific name for each species is listed in table 1 of the Appendix.

ACKNOWLEDGMENTS

Appreciation is extended to the captains and crewmen of both the commercial and POFI vessels for their cooperation and to the scientific personnel who made the observations, in many instances under adverse conditions. Deserving of special thanks are the following commercial vessel captains and owners: S. Jangaard, L. Jangaard, A. Ottness, E. Oswald, H. Sperling, and J. Parsons. The bathythermograph temperature sections and the Christmas Island temperature graph were prepared by T. S. Austin.

METHODS OF COLLECTION AND ANALYSIS OF DATA

The nature and extent of our observations varied during 1954. On the two POFI experimental cruises observations on the catch and fishing operations were obtained by trained personnel. The commercial vessels carried only a single government observer or none at all; in the latter case the vessel captain recorded information in a log provided by POFI (fig. 1).

PACIFIC OCEANIC FISHERY INVESTIGATIONS
LONGLINE FISHING LOG

Vessel _____ Noon position _____ (Lat.) _____ (Long.) Dir. of set _____ Date _____

Noon: Wind force _____ Wind direction _____ RPM of set _____

TIME OF SETTING AND HAULING

First basket set	Last basket set	First basket hauled	Last basket hauled

GEAR

Fabric	
Number baskets set	Number baskets lost
Wire	
Number reels set	Number reels lost

At the first day's fishing sketch one basket or reel of each type of gear used. Record any modifications of gear on this form.

Bait: Kind(s) _____

Bait hooking method: Single _____ Double _____ (Check one)

Bait condition: Good _____ Fair _____ Poor _____ (Check one)

CATCH

Species	Number not shark bitten	Number shark bitten	Approx. average weight	Remarks
Yellowfin				
Bigeye				
Skipjack				
Albacore				
Black marlin				
White marlin				
Striped marlin				
Sailfish				
Sharks				

Recorder: _____ 11/3/54

Figure 1.--Pacific Oceanic Fishery Investigations' Longline Fishing Log.

Also, certain facilities and equipment, such as a bathythermograph winch, were not available on the commercial boats. As a result, the information from this source was not as complete as that from the POFI research vessels.

There were differences in the gear used from cruise to cruise both in respect to design and materials. To some extent these variations affected the catch rates. The longline gear with fabric mainline had as few as 6 and as many as 15 droppers per basket. Shomura and Murphy (1955) found that catch rates of yellowfin tuna in terms of fish per 100 hooks taken on gear with 11 droppers per basket should be multiplied by 1.52 to make them equivalent to catch rates on gear with 6 droppers per basket. Catch rates are given in terms of 11-hook gear, except in our comparison of American and Japanese fishing results at different longitudes. In this case rates of American vessels have been converted to 6-hook equivalents to make them comparable to the Japanese catch rates. The length of the droppers on 6-hook gear used on cruise 15 of the Charles H. Gilbert was 10 fathoms as compared with the usual 3 fathoms, but the difference is not believed to have markedly altered the catch rates, for the efficiency of long and short droppers has been compared and no significant difference demonstrated (Shomura and Murphy 1955). On this same cruise both 1- and 10-fathom float lines were used on some stations (tables 6 and 7 - Appendix), but previous experiments have indicated no significant difference in yellowfin catch rates resulting from the use of different length float lines (Murphy and Shomura 1953b).

Longline gear with the mainline of wire rope was used on two commercial ventures of the Commonwealth (cruises 1 and 2), Oceanic and Brothers (cruises 1 and 2), and one experimental fishing cruise of the John R. Manning (cruise 20). The steel gear was introduced to increase the efficiency of operation of longline fishing. Steel mainline can be spooled on a reel rather than coiled in baskets, which results in a very considerable saving of labor. There is some

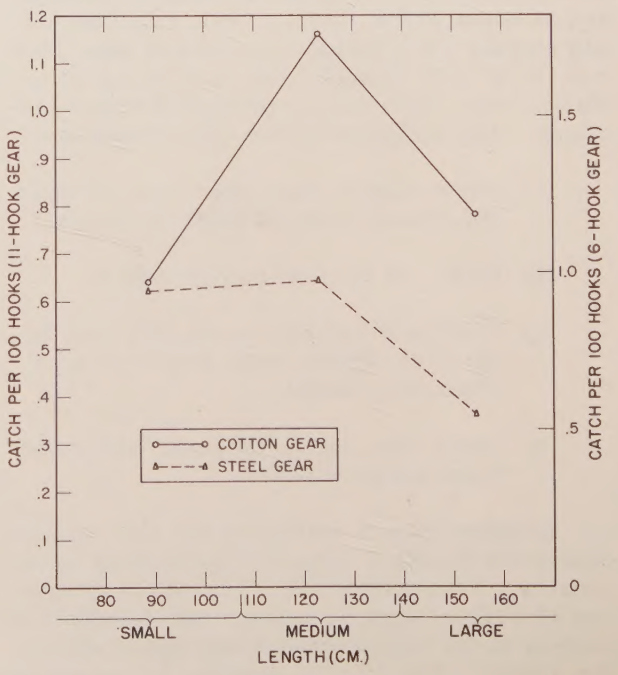


Figure 2.--Comparison of steel and cotton gear yellowfin catch rates by size groups, John R. Manning cruise 20.

indication, however, that the steel gear has a lower catch rate than fabric gear. A comparison of the two, made on John R. Manning cruise 20, shows that the steel line caught about the same number of small yellowfin, but that it caught relatively fewer medium and large yellowfin than the fabric gear (fig. 2). The steel gear probably does not offer the resiliency to the struggles of the fish that the fabric gear does, hence a higher proportion of the larger tunas escape.

The amount of shark damage varies considerably from cruise to cruise. The numbers of shark-damaged yellowfin are included in calculations of abundance for each cruise, but, of course, should not be counted when calculating the number of marketable fish.

VESSEL EFFICIENCY

It has been frequently observed that with equivalent fishing effort some vessels are able to produce good catches while others fishing under seemingly the same conditions and in the same general area do poorly. The reasons for this, perhaps, lie in the skill, experience, etc., of the fishermen involved. In an intensive fishery individual differences in experience will be smoothed out in the seasonal or annual averages. In 1954, only eight vessels took part in longline fishing in the area of study, and one of these made only a single trip; also the waters, and, in some instances, the fishing method, were unfamiliar to the fishermen. Hence it is possible that some of the variation among catches made at different times of the year resulted from differences among vessels and not entirely from a seasonal variation in the abundance of yellowfin.

Despite this possibility, it appears that differences among vessels did not seriously affect the catch rates, since there were only gradual changes in the catch rates between consecutive cruises, and when two or three vessels fished simultaneously, as did the North American and the Alrita, the catch rates were in general similar (fig. 3). The 95-percent fiducial limits estimated by Murphy and Elliott (1954) for longline catch rates, if assigned to the rates of each vessel, would doubtless overlap.

Differences among local fishing areas could also affect the catch rates. In Hawaii, for example, Otsu (1954) found that certain longline boats fished in a certain area whether productive or not, while others fished in areas which were known to be the most productive at a particular season. On the basis of the meager data available from the Line Islands area it appears that yellowfin move around these rather small islands in a more or less random manner. This, coupled with the fact that the vessels moved about from day to day, makes it very doubtful that location of fishing biased the catches.

YELLOWFIN ABUNDANCE

Latitudinal Variation

In February to April 1954 the Charles H. Gilbert (cruise 15) occupied fishing stations on

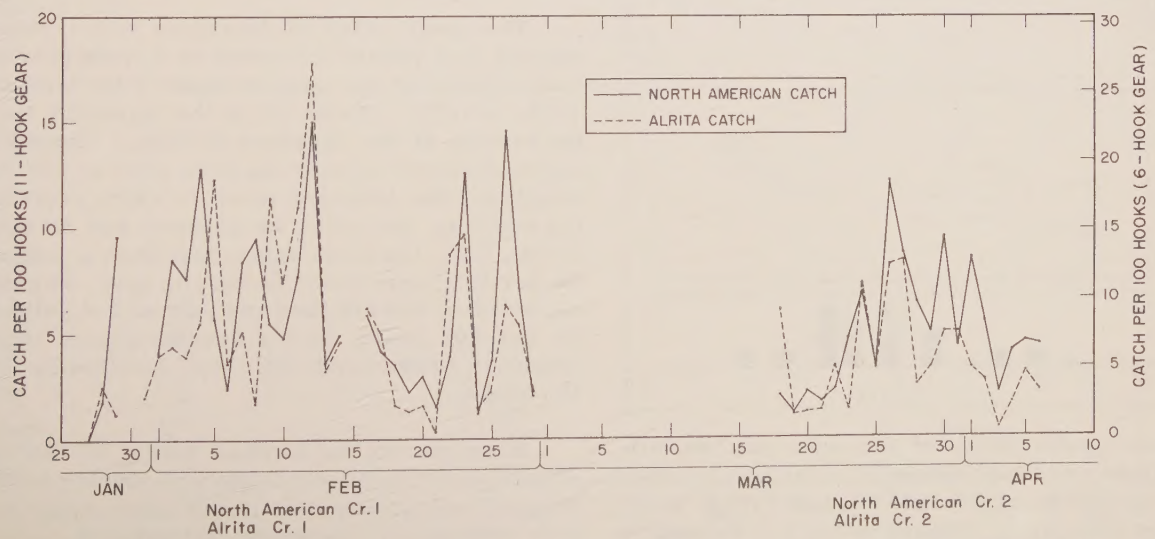


Figure 3.--Daily variability of yellowfin catch between the North American and the Alrita in the Line Islands.

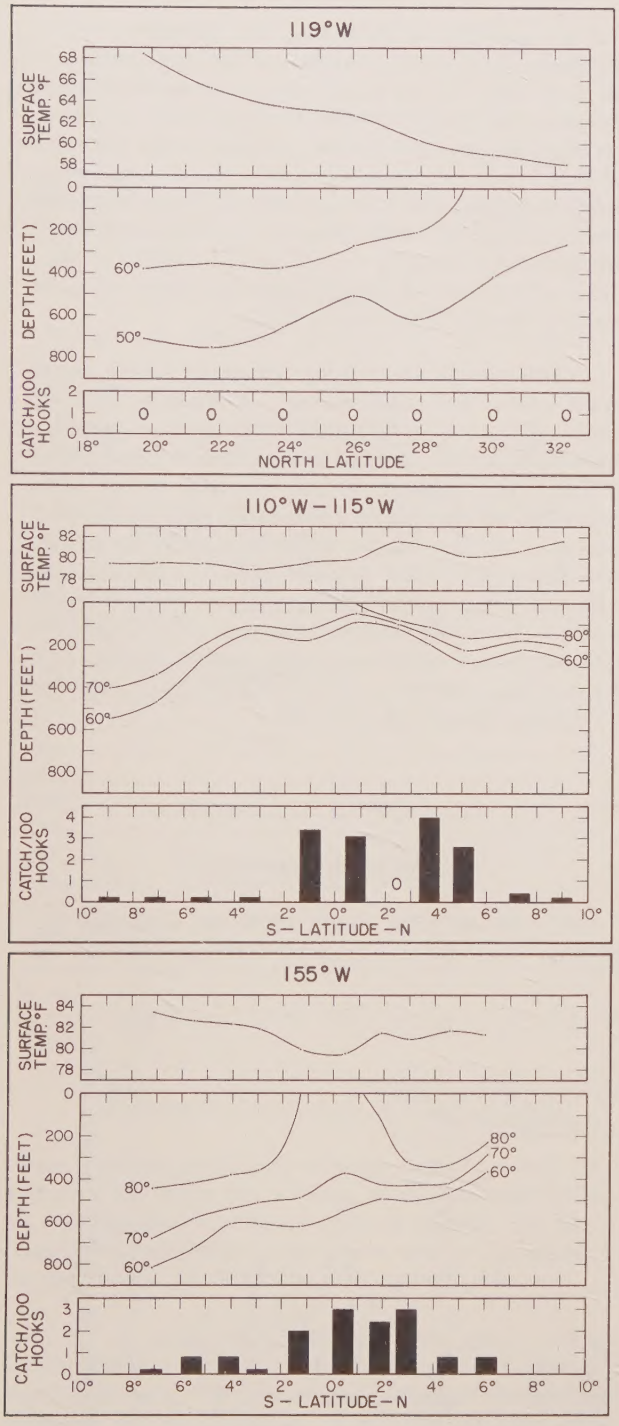


Figure 4.--Variation of yellowfin catches with latitude and temperature on three station lines along 119°W., 110°-115°W., and 155°W. longitude; Charles H. Gilbert cruise 15, February to April. /If no yellowfin were taken a zero is shown at that latitude./

three north-south lines in the eastern and central Pacific. On this cruise 6- and 11-hook gear was fished simultaneously; therefore, 6-hook catch rates have been converted to 11-hook equivalents and averaged with the 11-hook catch rates. The variation of yellowfin catches with latitude and temperature is shown in figure 4. The first series on 119°W. longitude extending from 33°N. to 20°N. latitude yielded no yellowfin. The section on 110°-115°W. longitude, from 10°N. to 10°S. latitude produced the best catches (>2 yellowfin per 100 hooks) between 6°N. and 1°S. latitude. Running north on 155°W. longitude the highest catch rates (>2 yellowfin per 100 hooks) were made between 2°S. and 3°N. latitude. Most of these stations were outside the influence of land (more than 60 miles) so that the catch rates are readily comparable with previous results from the open ocean. The results from along the Equator are consistent with past experience. Shomura and Murphy (1955) found that the center of abundance of yellowfin at several longitudes was at or a little north of the Equator during 1953.

Longitudinal Variation

The Japanese carried out extensive long-line fishing in the equatorial Pacific during 1954. Records of their catches are available (Nomura 1954-55) for each month of the year. It is difficult to compare these data with ours because the Japanese in general fished farther to the north during many months of the year (probably in search of better bigeye catches) than did U.S. fishermen or the POFI research vessels. Nevertheless, certain aspects of seasonal and geographic variation are susceptible to analysis.

The catch rates of American and Japanese vessels are plotted in terms of 6-hook gear for each month of the year in figure 5 for latitudes 11°S. to 10°N. (Table 18 in the Appendix lists the results of the Japanese fishing.) Considering the Japanese data for the area west of 170°W. longitude, the seasonal trend in catch rates is the same as described by Shomura and Murphy (1955), i.e., low catch rates, less than 2 yellowfin per 100 hooks from January to May, slightly higher catch rates in June and July of 2-4 yellowfin per 100 hooks, with a decrease again from August to December to less than 2 yellowfin per 100 hooks.

In comparing the catches west of 170°W. with those of the Line Islands area during 1953, Shomura and Murphy (1955) found evidence of an east-west shift in the equatorial yellowfin population. During 1954 there was some indication of a similar shift in the center of abundance.

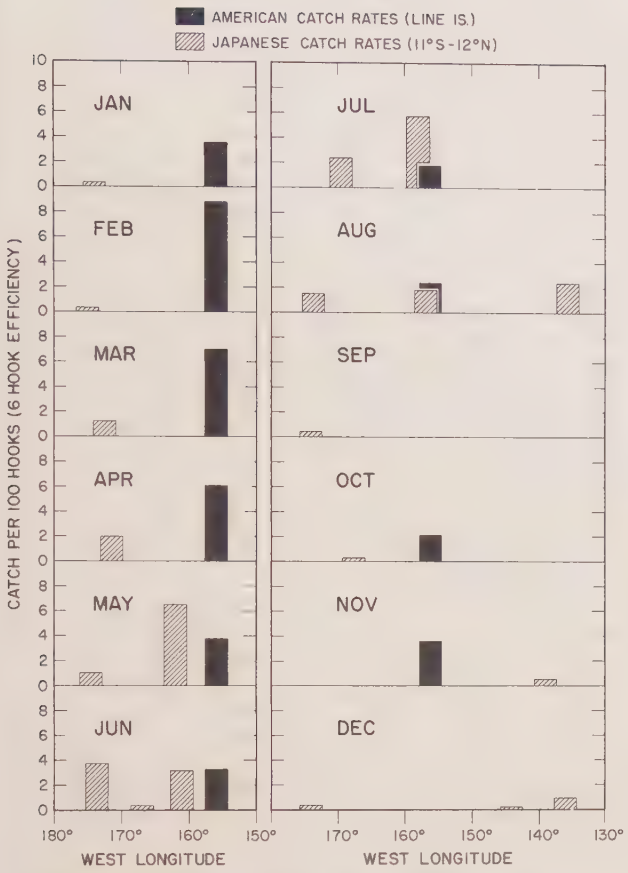


Figure 5.--Catch rates of yellowfin from the equatorial Pacific (11°S. - 10°N. latitude) obtained by American and Japanese vessels during 1954.

When the catches were high west of the Line Islands area (around 160°W.) they were lower in the vicinity of the Line Islands and conversely (fig. 5).

During the month of July 1954 Japanese vessels fishing near the Line Islands area experienced markedly higher catch rates than the American vessels. This is difficult to evaluate in view of the wide variability in the very few samples obtained by American vessels during July. However, the Japanese did most of their fishing south and somewhat west of the Americans and used fabric instead of steel gear.

Line Islands

General: A seasonal trend can be seen in the yellowfin catch rates from the vicinity of the Line Islands during 1954 (fig. 6). Starting with high catch rates in February, there was a gradual decrease to a very low level during the latter part of July, early August, and during October. During November there was a slight increase over the summer months, but the rates remained considerably lower than those of the first few months of the year. The catch rates of the Japanese longline vessels based at Pago Pago, American Samoa, show a similar decline (fig. 7) during the early months of 1954 (Van Campen 1954).

This trend in catch rates during 1954 is sharply divergent from past observations, for Shomura and Murphy (1955) found that the greatest abundance in the Line Islands area occurred from July through September during 1951-1953. This dissimilarity in the seasonal trend of catch

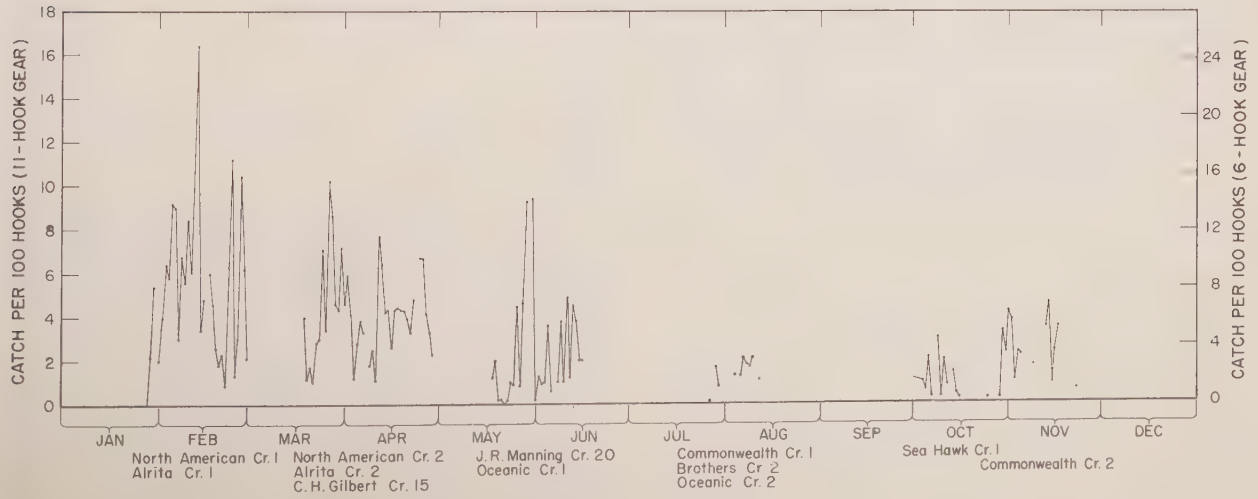


Figure 6.--Daily catch rates for yellowfin in the Line Islands during 1954.

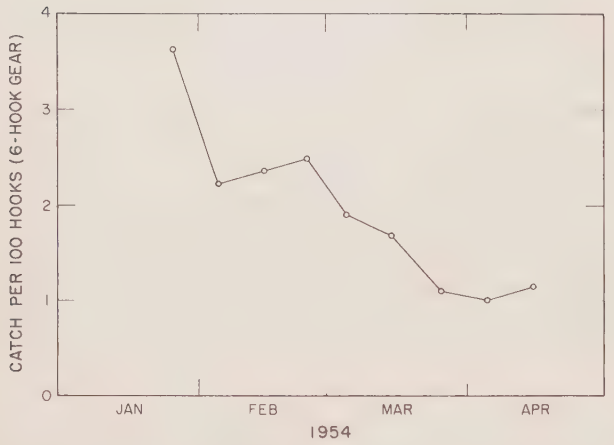


Figure 7.--Yellowfin catch rates by 10-day periods from 0° to 20°S. and 165°W. to 180° by vessels based at Pago Pago, American Samoa. /Data from Van Campen 1954./

rates is good evidence of a change in the abundance or distribution of the yellowfin. The possibility that this change is related to a change in the environment will be considered later.

Discussion of individual cruises: The results of concentrated fishing around Christmas Island by the North American and Alrita during January to March and March to May have already been discussed by Iversen and Murphy (1954). In the former period, yellowfin catches averaged 5.6 but ranged from 0 to 17.8 per 100 hooks for individual stations; in the latter period, they averaged 4.4 but ranged from 0.4 to 12.2 per 100 hooks. As shown by the summary of catch rates according to sectors (figs. 8 and 9) no one area seems to be significantly superior to the rest. We may conclude therefore that during this period the yellowfin were distributed in a somewhat random fashion. Only a few catches were made elsewhere in the Line Islands.

On John R. Manning cruise 20 (fig. 10), in May-June 1954, the best catch rates of 9.3 and 9.4 yellowfin per 100 hooks were made near Fanning and the poorest, 0 to 0.2 yellowfin per 100 hooks, near Palmyra.

On Oceanic cruise 1 (fig. 11), the fishing was generally poor, with an average catch rate of 0.9 for Christmas Island and an average of 1.5 for the seven stations in the vicinity of Fanning Island. The Brothers cruise 2 (fig. 12) occupied only four stations each at Fanning and Christmas Islands, with very low catch rates for both islands. The rate at Fanning averaged 0.9 and that at Christmas 1.0 yellowfin per 100 hooks. On Oceanic cruise 2 (fig. 13), only a single

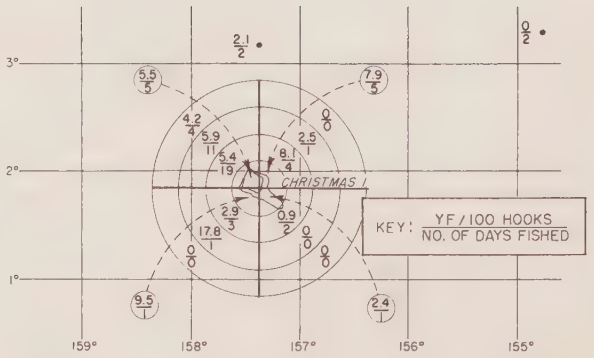


Figure 8.--Jangaard longline fishing (Alrita and North American catches combined), cruise 1, January-March.

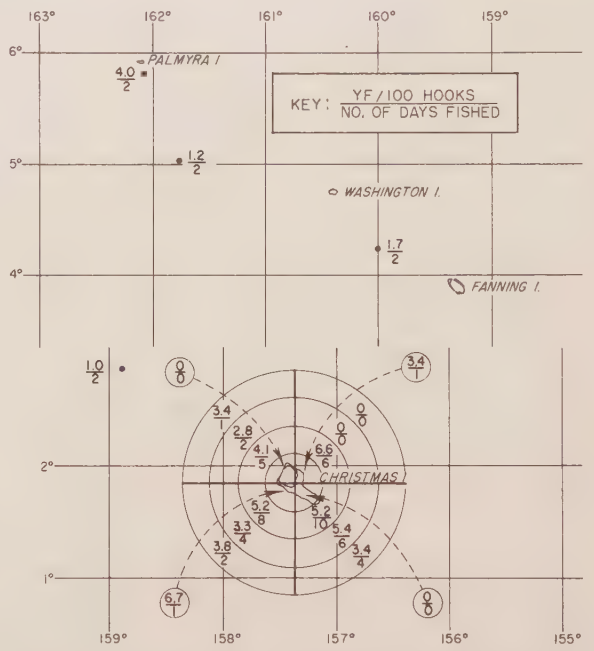


Figure 9.--Jangaard longline fishing (Alrita and North American catches combined), cruise 2, March-May.

station was occupied near Fanning; eight fishing days were spent in the vicinity of Christmas Island and show a high of 3.4 and a low of 0.2 yellowfin per 100 hooks.

On Commonwealth cruise 1 (fig. 14), fishing centered in the vicinity of Christmas Island. A high catch rate of 3.3 and a low of 0 yellowfin per 100 hooks were obtained. The Sea Hawk also fished in the vicinity of Christmas Island with poor results (fig. 15). Her best catch rate of 3.0 yellowfin per 100 hooks was made in the lee

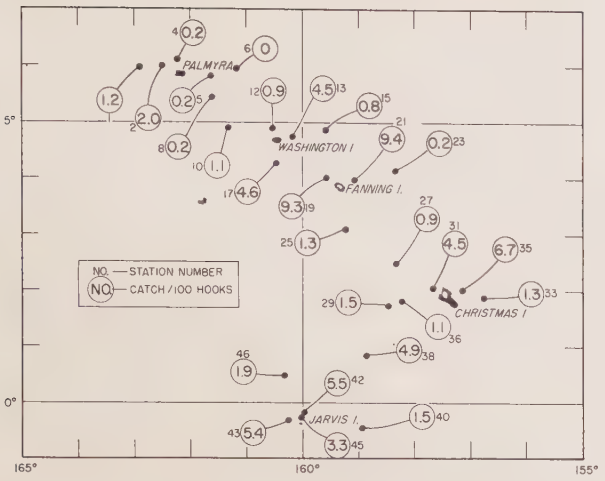


Figure 10.--John R. Manning longline fishing, cruise 20, May-June.

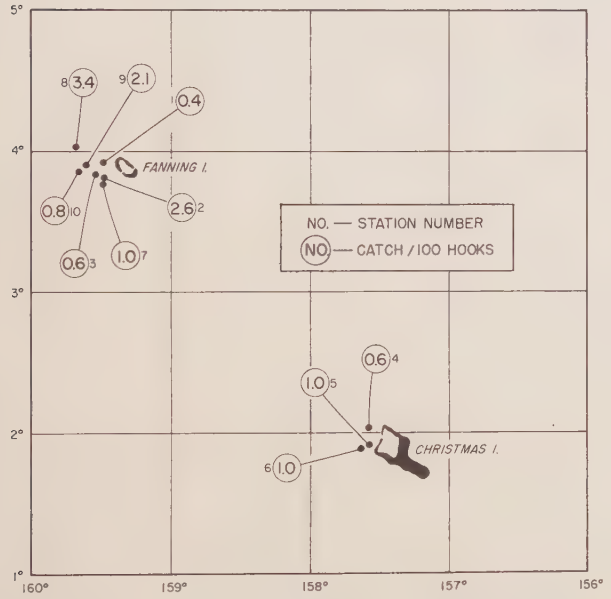


Figure 11.--Oceanic longline fishing, cruise 1, May-June.

of the island. On the second cruise of the Commonwealth fishing was improved, with high catch rates of more than 4 yellowfin per 100 hooks at both Christmas and Fanning Islands and one low catch rate at Palmyra of 0.6 yellowfin per 100 hooks (fig. 16). The average for Fanning Island, 3.0 yellowfin per 100 hooks, was only slightly higher than the average catch rate for Christmas Island, 2.3 yellowfin per 100 hooks.

Although it is difficult to summarize these rather variable and patchy results, we believe

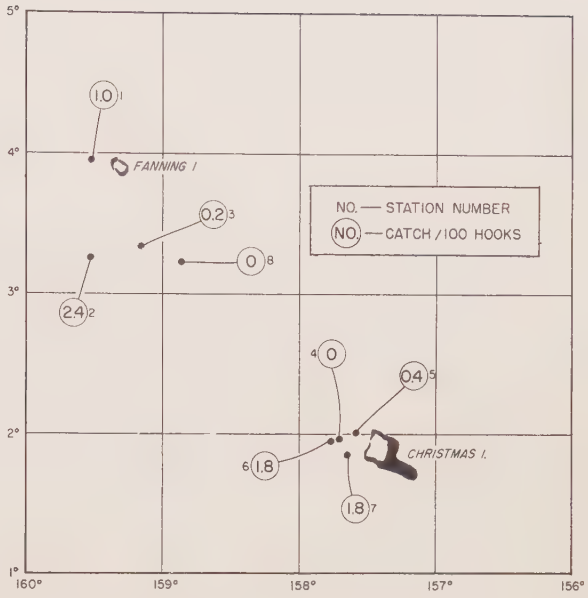


Figure 12.--Brothers longline fishing, cruise 2, July-August.

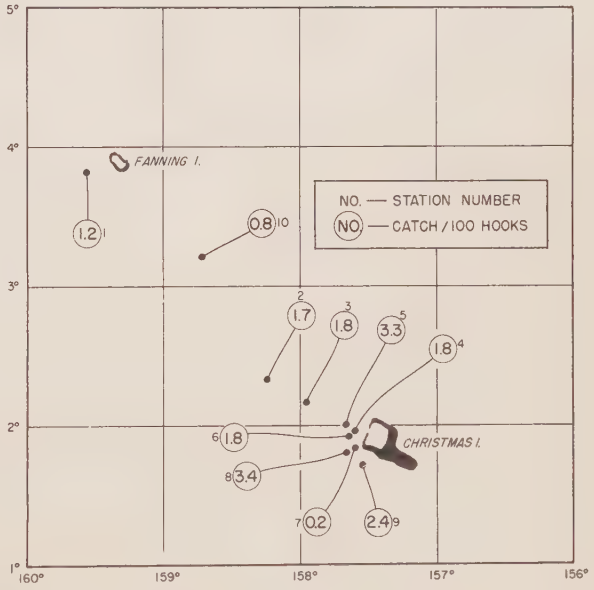


Figure 13.--Oceanic longline fishing, cruise 2, July-August.

they contain two important indications. First, the deep-swimming yellowfin do not appear to congregate on one side of an island, leeward or windward, in preference to the other; and second, although the data do not permit a proper comparison of differences among islands, slightly better catches were made in the vicinity of Fanning Island than at Christmas or the other areas fished (figs. 10, 11, 12, 16).

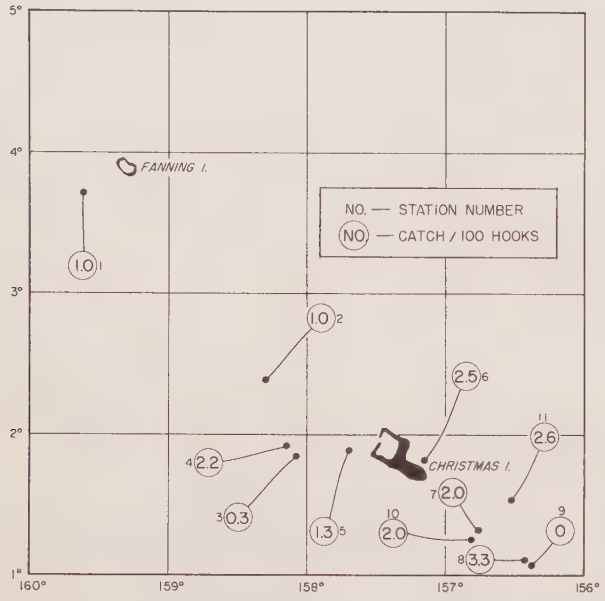


Figure 14.--Commonwealth longline fishing, cruise 1, July-August.

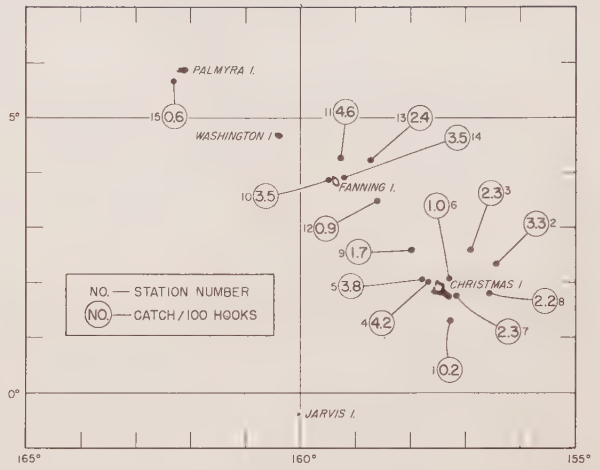


Figure 16.--Commonwealth longline fishing, cruise 2, October-November.

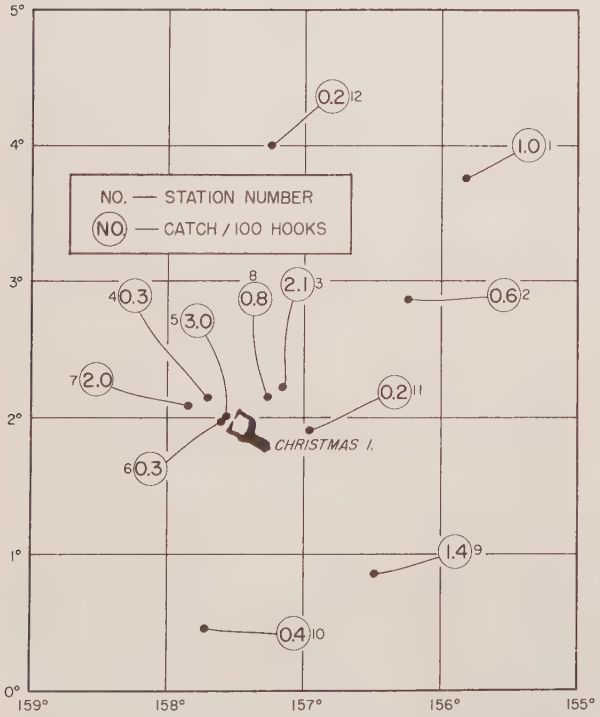


Figure 15.--Sea Hawk longline fishing, October.

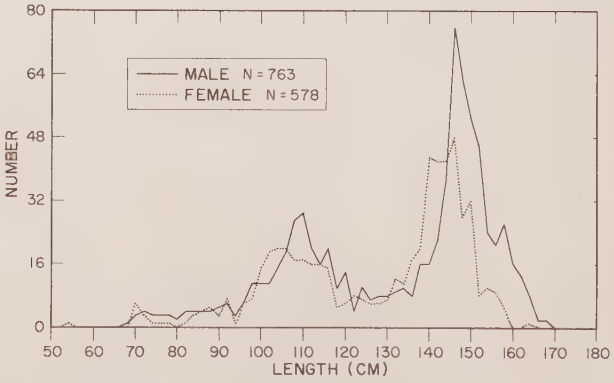


Figure 17.--Yellowfin size distributions by sex taken on fabric gear in the Line Islands area during 1954 (data in Appendix table 17).

YELLOWFIN CATCH COMPOSITION

There are no apparent differences in the sex ratio or size distribution between yellowfin caught during 1954 and those caught in past years (Murphy and Shomura 1955, fig. 11 and Shomura and Murphy 1955, fig. 11) that would help explain the decreased abundance during 1954 and the absence of the midsummer upswing in catch rates. As usual the males were predominant in number, especially in the very large fish (fig. 17).

OBSERVATIONS ON THE ENVIRONMENT

In conjunction with the experimental fishing, extensive observations were made on the sea temperature. In the long-term approach these observations are intended to help explain seasonal and annual fluctuations in catch rates of tuna. Tester (1956) points out a high positive correlation between sea temperatures and yellowfin catch. He does not regard the temperature change as the direct cause of the change in tuna abundance; rather, that temperature indicates the age of the water subsequent to upwelling. Since upwelling brings to the surface water low in temperature and high in nutrients, he regards the coolest water as newly upwelled and warmer water as water that has been longer at the surface and has remained in the area sufficiently long to permit tuna forage to develop in it.

Since November 1953 the U. S. Fish and Wildlife Service has obtained weather and hydrographic data from the weather station on Christmas Island. At that time instruments and aid were given to improve the station maintained by a plantation weather observer at the village of London on the lee (west) side of the island. Differences between observations made at the island station and in the open ocean are being examined. At present it appears that on-shore water temperatures are consistently lower than those off-shore, but they may provide an index of oceanic conditions.

Surface temperatures obtained at the Christmas Island station during 1954 show a trend generally similar to the trend in the catch rates of yellowfin (fig. 18). Both sea surface temperatures and yellowfin catch rates were relatively high early in the year and both were relatively low during the late summer and fall months.

Tester (1956, fig. 3) used yellowfin catches and temperatures collected in the equatorial Pacific over several years to define the temperature-yellowfin relationship. In this report we are dealing with a large number of observations taken within one year and all from the Line Islands area. Since the same interpretation can be given to the two somewhat dissimilar lots of data, the hypothesis that there is a significant relationship between the temperature of the water and the abundance of yellowfin tuna appears reliable.

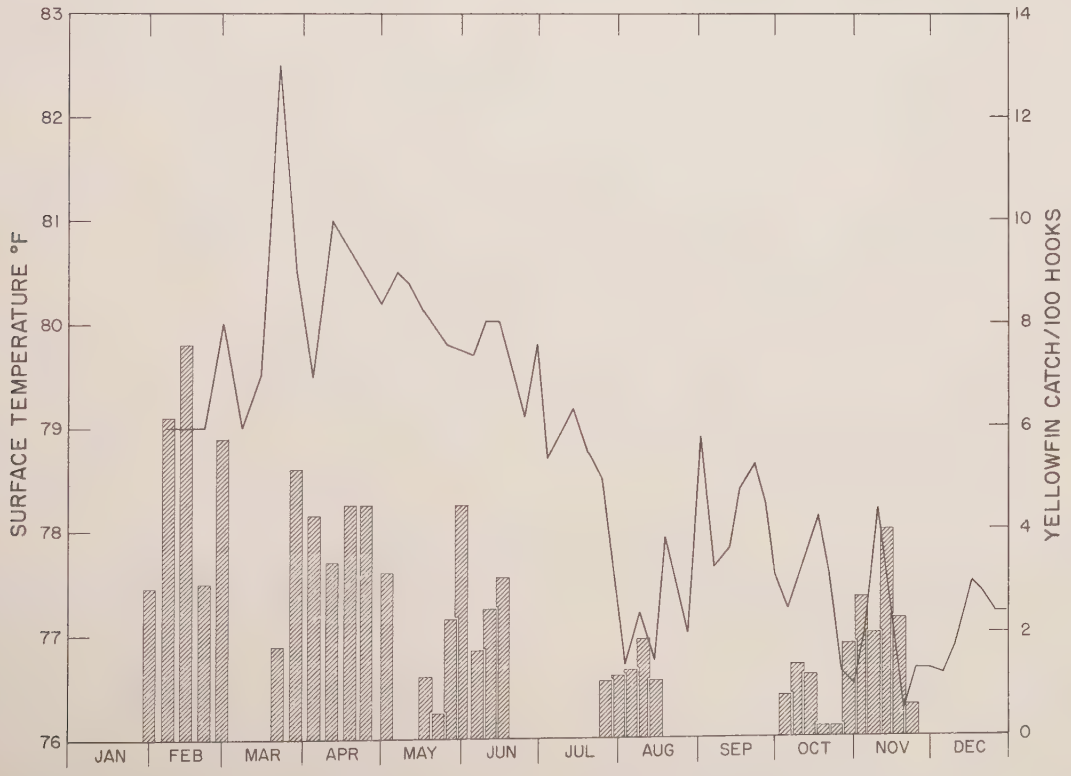


Figure 18.--Surface temperatures at Christmas Island and Line Islands yellowfin catches during 1954 by 5-day periods. [Only single weekly temperature observations are available through March 12.]

SHARKS AND SHARK DAMAGE

The depredation on hooked yellowfin tuna by sharks requires brief examination, since it affects the monetary return to fishermen from any longline venture. Not all tunas which are shark damaged are unsaleable, however, since some may be only superficially damaged and hence acceptable to canneries. Consequently, the records kept by POFI observers tend to exaggerate the loss from this source since the extent of damage to each shark-bitten fish was usually not evaluated.

The loss due to sharks during 1954 does not differ greatly from previous years. In 1954 an average of 20 percent of hooked yellowfin were damaged. One extreme occurred on a cruise of the Oceanic when 46 percent of the yellowfin caught were either partially mutilated or totally destroyed by sharks. The lowest figure for any cruise in 1954 was the 10 percent damage reported by the North American on cruise 1.

The relationship of the percentage of shark damaged to hooked yellowfin and the longline catch rates of all species of sharks (white-tipped, silky, great blue, and bonito) taken during 1954 in the Line Islands region is illustrated in figure 19.

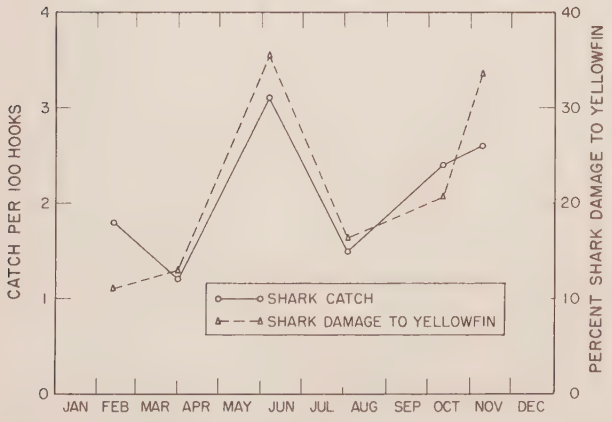


Figure 19.--Shark catch rates on longlines and percentage of shark damage to hooked yellowfin in the Line Islands area during 1954.

The plotted points are mid-points of fishing periods, and where two or more vessels fished together the average shark catch rate and shark damage are used. As would be expected the amount of shark damage varies directly with the shark catch rates. Shark catch rates, however, are not correlated with the abundance of yellowfin (compare figs. 19 and 6).

SUMMARY

1. There were thirteen longline fishing cruises to the central equatorial Pacific during 1954. Most of these were commercial ventures to the vicinity of the Line Islands.

2. The year 1954 marked some first events in the central equatorial Pacific: (1) the first commercial attempts to longline by American fishermen, (2) the first use of steel longline gear, and (3) first concentrated year-around fishing in the Line Islands area.

3. The seasonal trend of catch rates was lowest during August and October 1954, the period at which catch rates were highest for previous years.

4. The lack of distinct variation in yellowfin catch rates between different localities close to the Line Islands indicated a random distribution of the fish in respect to each individual island.

5. The sex ratio and size distribution in the yellowfin catch of 1954 were similar to the previous years.

6. A correlation between sea temperature and the catch of deep-swimming yellowfin was observed again in 1954, with the higher catch rates being associated with warmer surface temperatures.

7. The amount of shark damage to hooked yellowfin was about the same as in previous years and varied directly with the abundance of sharks.

LITERATURE CITED

IVERSEN, EDWIN S. and G. I. MURPHY
1955. What the Jangaard longline venture found in mid-Pacific. Pacific Fisherman 53(4):22, 25, 27.

MANN, HERBERT J.
1955. Construction details of improved tuna long-line gear used by Pacific Oceanic Fishery Investigations. U. S. Fish and Wildlife Service, Comm. Fish. Rev. 17(12):1-10.

MURPHY, GARTH I. and K. C. ELLIOTT
1954. Variability of longline catches of yellowfin tuna. U. S. Fish and Wildlife Service, Spec. Sci. Rept.--Fisheries No. 119, 30 pp.

MURPHY, GARTH I. and R. S. SHOMURA
1953a. Longline fishing for deep-swimming tunas in the central Pacific, 1950-1951. U. S. Fish and Wildlife Service, Spec. Sci. Rept.--Fisheries No. 98, 47 pp.

1953b. Longline fishing for deep-swimming tunas in the central Pacific, January-June 1952. U. S. Fish and Wildlife Service, Spec. Sci. Rept.--Fisheries No. 108, 32 pp.

1955. Longline fishing for deep-swimming tunas in the central Pacific, August-November 1952. U. S. Fish and Wildlife Service, Spec. Sci. Rept.--Fisheries No. 137, 42 pp.

NOMURA, TOSHIZO (Editor)
1954-55. Survey of the high-seas tuna fisheries based on landings at Misaki, Tokyo, and Yaizu. Published monthly by Kanagawa Prefecture Fisheries Experiment Station in Tuna Fishing, 9:1-25; 10:1-31; 11:1-31; 12:1-40; 13:1-44; 14-15:1-30, 31-54; 16:1-30; 17:1-34; 18:13-40; 19:1-16; 20:1-36.

OTSU, TAMIO
1954. Analysis of the Hawaiian long-line fishery, 1948-52. U. S. Fish and Wildlife Service, Comm. Fish. Rev. 16(9):1-17 (also issued as Separate No. 376).

SHOMURA, RICHARD S. and G. I. MURPHY
1955. Longline fishing for deep-swimming tunas in the central Pacific, 1953. U. S. Fish and Wildlife Service, Spec. Sci. Rept.--Fisheries No. 157, 70 pp.

TESTER, ALBERT L.
1956. Recent equatorial tuna research. Pan American Fisherman 10(8):10, 11, 21.

VAN CAMPEN, WILVAN G.
1954. Tuna fishing at American Samoa, January-April 1954. U. S. Fish and Wildlife Service, Comm. Fish. Rev. 16(11):1-9 (also issued as Separate No. 382).

APPENDIX

Annotated List of 1954 Cruises

Vessels: North American and Alrita (Jangaard expedition)
Cruise No.: 1
Cruise period: January 12 to March 7, 1954
Gear: The longline gear used differed only slightly from the most recent 11-hook gear used by POFI (Mann 1955). The major differences were the lengthening of the mainline to 1620 feet and the addition of 4 extra droppers, making a total of 15 droppers per basket.

Vessels: North American and Alrita (Jangaard expedition)
Cruise No.: 2
Cruise period: March 13 to May 15, 1954
Gear: The gear used was identical with the gear used on the first Jangaard expedition.

Vessel: Charles H. Gilbert
Cruise No.: 15
Cruise period: February 18 to April 26, 1954
Gear: Equal numbers of POFI 6- and 11-hook cotton gear were fished at all stations. The lengths of the droppers were 10 fathoms on the 6-hook gear and 3 fathoms on the 11-hook gear. Ten-fathom float lines were used on both gear types except at stations 7-32, at which both 1- and 10-fathom float lines were used.

Vessels: Oceanic and Brothers
Cruise No.: 1
Cruise period: May 20 to June 23, 1954
Gear: The mainlines used by both vessels were constructed of 5/64" hard lay Hackensack stainless steel cable made up into reels 1600 fathoms in length. The reels of cable were joined by means of Brummel hooks. A pair of bullet swivels 1 fathom apart were inserted every 45 fathoms along the mainline. Two sets of 3 brass beads were pressed on to the mainline between the pair of swivels. The droppers were attached between the swivels and beads. The gear on the Oceanic was usually made up with 11 or 14 hooks between floats. The Brothers usually set her lines with 14 hooks between buoys.

The float lines were made up of 40-pound tarred manila line with an A-K snap on the end and were either 10 or 25 fathoms in length. The floats used were of two types. One was the regular metal oxygen tank used by POFI and the other was 16-

inch diameter Japanese glass balls covered with netting. The droppers consisted of 2-1/2 fathoms of 16-pound tarred hemp, 1 fathom of galvanized wire leader and 9/10 hook.

Vessels: Oceanic and Brothers
Cruise No.: 2
Cruise period: July 14 to August 21, 1954
Gear: The gear used was identical with the gear used on the first cruise of the Oceanic and Brothers.

Vessel: Commonwealth
Cruise No.: 1
Cruise period: July 14 to August 21, 1954
Gear: The gear used was essentially the same as the gear used by the Oceanic and Brothers, but differed in several details. The mainlines used by the Commonwealth consisted of 5/64", 3 X 7 stainless steel cable. The floats were large Japanese glass balls. The float lines consisted of 10 fathoms of 9 thread Plymouth Manila (hard lay). The droppers consisted of 2 fathoms of 6 thread buoy Manila, 1 fathom of galvanized wire leader, and a 9/10 tuna hook. One basket was made up of 14 hooks.

Vessel: John R. Manning
Cruise No.: 20
Cruise period: May 11 to June 23, 1954
Gear: Whenever possible, equal numbers of POFI 11-hook cotton and steel gear were used. Other construction details were identifical.

Vessel: Sea Hawk
Cruise No.: 1
Cruise period: October 3 to 20, 1954
Gear: Ten-hook cotton gear (POFI design - 15-fathom hook spacing).

Vessel: Commonwealth
Cruise No.: 2
Cruise period: October 28 to November 22, 1954.
Gear: Both cotton and steel gear were used. The steel gear was composed of 100 hooks per reel and the cotton gear, 8 hooks per basket (POFI design - 15-fathom hook spacing).

Table 1.--List of common and scientific names of fishes used in this report

White-tipped shark, Pterolamiops longimanus (Poey)
Silky shark, Carcharhinus floridanus Bigelow, Schroeder and Springer
Great blue shark, Prionace glauca (Linnaeus)
Bonito shark, Isurus glaucus Müller and Henle
Marlin, Makaira sp.
Sailfish, Istiophorus orientalis (Temminck and and Schlegel)
Wahoo, Acanthocybium solandri (Cuvier and Valenciennes)
Dolphin, Coryphaena hippurus Linnaeus
Yellowfin tuna, Neothunnus macropterus (Temminck and Schlegel)
Bigeye tuna, Parathunnus sibi (Temminck and Schlegel)
Skipjack, Katsuwonus pelamis (Linnaeus)
Albacore, Germo alalunga (Bonnaterre)
Lancet fish, Alepisaurus sp.
Barracuda, Sphyraena barracuda (Walbaum)
Red snapper, Lutjanus bohar (Forskål)
Opah, Lampris sp.
Sunfish, Mola mola (Linnaeus)
Truncated sunfish, Ranzania truncata (Gmelin)
Broadbill swordfish, Xiphias gladius Linnaeus
Pelagic sting ray, Dasyatis atratus Ishiyama and Okada
Shortnosed spearfish, Tetrapturus angustirostris Tanaka

Table 2.--Summary of fishing localities and catches on 15-hook gear, North American cruise 1

Sta.	Date	Position[1]		Number of hooks	Total catch							
					Yellowfin		Number of fish					
		Latitude	Longitude		Number	Per 100 h.	Big-eye	Alba-core	Skip-jack	Marlin	Shark	Miscellaneous
1	1/27*	3°20'N.	154°45'W.	375	0	0	1	-	-	-	6	1 lancet fish
2	1/28	2°18'N.	157°05'W.	618	11 (2)[2]	1.8	-	-	1	3	16	
3	1/29	2°04'N.	157°50'W.	356	34 (8)	9.6	2	-	-	-	14	
4	2/1 *	1°42'N.	157°38'W.	630	26 (6)	4.1	-	-	-	-	-	
5	2/2	1°58'N.	157°34'W.	657	56 (7)	8.5	-	-	-	1	20	1 dolphin, 1 wahoo
6	2/3	2°01'N.	157°33'W.	738	56 (6)	7.6	-	-	-	-	22	1 dolphin, 1 wahoo
7	2/4	1°55'N.	157°36'W.	718	92 (7)	12.8	-	-	-	1	20	2 sailfish, 1 sunfish, 1 wahoo
8	2/5	1°50'N.	157°36'W.	858	49 (6)	5.7	1	-	-	-	8	2 dolphin, 1 sailfish
9	2/6 *	1°40'N.	157°17'W.	670	16	2.4	2	-	-	-	16	3 red snapper, 1 wahoo
10	2/7	1°52'N.	157°35'W.	873	73 (18)	8.4	-	-	-	1	31	1 barracuda, 1 wahoo
11	2/8	1°47'N.	157°30'W.	800	76 (6)	9.5	1	-	-	1	16	2 wahoo
12	2/9 *	2°02'N.	157°58'W.	840	46 (6)	5.5	-	-	1	1	5	1 lancet fish
13	2/10*	2°11'N.	158°04'W.	1,035	50 (5)	4.8	-	8	2	1	10	1 wahoo
14	2/11*	2°06'N.	157°42'W.	1,050	81 (1)	7.7	-	3	-	1	-	
15	2/12*	2°02'N.	157°52'W.	1,050	158 (1)	15.0	1	2	-	-	-	
16	2/13*	2°03'N.	158°15'W.	750	27 (2)	3.6	-	-	1	-	4	
17	2/14*	1°52'N.	157°34'W.	690	34 (4)	4.9	-	-	-	-	3	
18	2/16	1°56'N.	157°42'W.	975	58 (5)	5.9	-	-	1	-	11	2 wahoo
19	2/17	2°01'N.	157°46'W.	887	37	4.2	-	-	1	-	7	
20	2/18	2°08'N.	157°52'W.	863	30 (3)	3.5	2	-	3	-	16	
21	2/19*	2°04'N.	157°30'W.	1,020	22 (6)	2.2	-	-	-	-	14	
22	2/20	1°29'N.	157°36'W.	730	22 (2)	3.0	-	-	2	1	9	
23	2/21*	1°30'N.	157°15'W.	870	13 (2)	1.5	-	-	-	-	1	
24	2/22	1°51'N.	157°08'W.	720	28 (3)	3.9	-	-	-	1	21	1 lancet fish, 2 wahoo
25	2/23*	1°57'N.	156°54'W.	780	98 (24)	12.6	1	-	-	1	19	
26	2/24*	2°00'N.	158°05'W.	900	11 (1)	1.2	-	-	10	-	2	
27	2/25*	2°09'N.	157°23'W.	780	29 (3)	3.7	2	-	-	-	19	
28	2/26*	1°56'N.	157°15'W.	840	123 (12)	14.6	-	-	-	-	12	3 wahoo
29	2/27*	1°55'N.	157°11'W.	990	70 (3)	7.1	-	-	-	-	20	
30	2/28*	3°10'N.	157°23'W.	690	14 (7)	2.0	-	-	-	-	27	1 wahoo
Total				23,753	1,440 (156)	177.3	13	13	20	13	369	
Average					48.0 (5.2)	5.9	0.5	0.4	0.7	0.4	12.3	

* Indicates days no count of hooks was maintained.

[1] Position where first basket set. [2] Numbers in parentheses are shark-damaged fish and are included in the adjacent daily catch.

Table 3.--Summary of fishing localities and catches on 15-hook gear (from log maintained by Lars Jangaard), Alrita cruise 1

Sta.	Date	Noon position		Estimated number of hooks	Total catch							
					Yellowfin		Number of fish					
		Latitude	Longitude		Number	Per 100 h.	Big-eye	Alba-core	Skip-jack	Marlin	Shark	Miscellaneous
1	1/27	3°20'N.	154°57'W.	390	0	0	3	-	-	-	6	
2	1/28	2°18'N.	157°20'W.	630	16 (1)[1/]	2.5	1	-	2	-	7	
3	1/29	2°10'N.	157°45'W.	930	11 (2)	1.2	1	-	-	-	15	
4	1/31	1°50'N.	157°40'W.	645	13 (2)	2.0	-	-	-	-	9	
5	2/1	1°50'N.	157°40'W.	600	24 (4)	4.0	-	-	-	1	12	
6	2/2	2°00'N.	157°35'W.	675	30 (3)	4.4	1	-	-	2	24	
7	2/3	2°00'N.	157°30'W.	750	29 (8)	3.9	-	-	-	-	25	
8	2/4	2°03'N.	157°32'W.	750	41 (5)	5.5	-	-	-	-	14	
9	2/5	2°05'N.	157°32'W.	900	111 (18)	12.3	-	-	-	-	33	
10	2/6	2°03'N.	157°32'W.	750	27 (2)	3.6	-	-	-	-	18	
11	2/7	2°03'N.	157°35'W.	900	46 (7)	5.1	-	-	-	1	6	
12	2/8	1°50'N.	157°35'W.	825	14	1.7	-	-	-	1	10	
13	2/9	2°06'N.	157°50'W.	900	103 (5)	11.4	-	-	1	-	12	1 sailfish
14	2/10	2°04'N.	158°10'W.	1,050	78 (3)	7.4	-	4	1	1	17	1 sailfish
15	2/11	1°51'N.	157°55'W.	1,050	115 (2)	11.0	2	4	-	-	12	
16	2/12	1°47'N.	157°55'W.	975	174 (1)	17.8	-	4	-	1	6	
17	2/13	2°00'N.	157°55'W.	825	26 (5)	3.2	-	-	-	1	9	1 wahoo
18	2/14	4 mi. off S.W. Pt., Christmas I.		825	38 (12)	4.6	-	-	-	-	26	
19	2/16	1°58'N.	157°45'W.	975	60	6.2	1	-	-	-	14	
20	2/17	2°05'N.	157°40'W.	900	45 (1)	5.0	1	-	2	-	10	
21	2/18	2°07'N.	157°50'W.	900	14	1.6	-	-	1	-	6	1 sailfish
22	2/19	2°03'N.	157°37'W.	900	12	1.3	-	-	-	1	12	
23	2/20	1°36'N.	157°30'W.	825	13 (2)	1.6	-	-	-	-	6	
24	2/21	1°25'N.	157°20'W.	870	3	0.3	-	-	-	-	5	
25	2/22	1°50'N.	157°07'W.	750	65 (27)	8.7	-	-	-	-	70	
26	2/23	1°50'N.	156°55'W.	750	73 (23)	9.7	-	-	-	-	46	
27	2/24	2°00'N.	157°58'W.	900	13 (2)	1.4	-	1	3	-	6	
28	2/25	5 mi. N.W. of N.W. Pt.		900	20 (7)	2.2	-	-	-	-	32	
29	2/26	2°00'N.	157°08'W.	945	60 (2)	6.3	1	-	1	-	5	
30	2/27	1°55'N.	157°10'W.	900	49 (7)	5.4	-	-	-	-	8	
31	2/28	3°14'N.	157°08'W.	675	15 (1)	2.2	1	1	-	-	-	
Total				25,560	1,338 (152)	153.5	12	14	11	9	481	
Average					44 (4.9)	5.0	0.4	0.4	0.4	0.3	16	

[1/] Numbers in parentheses are shark-damaged fish and are included in the adjacent daily catch.

Table 4.--Summary of fishing localities and catches on 15-hook gear, North American cruise 2

Sta.	Date	Noon position		Number of hooks	Total catch							
					Yellowfin		Number of fish					
		Latitude	Longitude		Number	Per 100 h.	Big-eye	Alba-core	Skip-jack	Marlin	Shark	Miscellaneous
1	3/18	5°43'N.	162°16'W.	405	8 (2)1/	2.0	-	-	-	-	47	
2	3/19	4°56'N.	161°53'W.	675	8 (2)	1.2	-	-	2	2	5	
3	3/20	4°10'N.	159°57'W.	647	14 (4)	2.2	-	-	2	1	12	1 broadbill, 1 lancet fish, 1 wahoo
4	3/21*	2°52'N.	158°56'W.	900	6	0.7	-	-	5	-	16	2 wahoo
5	3/22	2°02'N.	157°56'W.	864	20 (1)	2.3	-	-	2	-	7	1 lancet fish
6	3/23*	5 mi. W. of Christmas I.		750	35 (5)	4.7	-	-	1	-	34	
7	3/24	7 mi. E. of N.E. Pt.		869	60 (10)	6.9	-	-	-	3	16	1 lancet fish, 1 wahoo
8	3/25*	7 mi. E. of N.E. Pt.		975	32 (4)	3.3	-	-	-	1	17	1 wahoo
9	3/26	15 mi. E. of N.E. Pt.		959	117 (21)	12.2	-	1	2	1	11	1 wahoo
10	3/27*	15 mi. E. of S.E. Pt.		990	87 (15)	8.8	1	-	3	3	16	1 wahoo
11	3/28	15 mi. E. of S.E. Pt.		924	59 (36)	6.4	-	-	-	4	29	
12	3/29*	15 mi. E. of S.E. Pt.		975	49 (3)	5.0	-	1	-	3	6	
13	3/30	1°20'N.	157°10'W.	918	87 (13)	9.5	-	-	1	1	17	1 lancet fish
14	3/31*	1°06'N.	157°00'W.	990	43 (3)	4.3	-	-	-	1	10	
15	4/1	10 mi. W. of Sta. 14		918	78 (7)	8.5	-	-	-	3	9	
16	4/2	1°06'N.	157°33'W.	944	52 (4)	5.5	-	-	2	2	9	
17	4/3	1°26'N.	157°50'W.	951	20 (6)	2.1	1	-	-	-	3	1 lancet fish
18	4/4	1°31'N.	157°28'W.	943	39 (5)	4.1	-	-	-	1	3	
19	4/5*	1°31'N.	157°10'W.	990	45 (8)	4.5	-	1	1	1	17	1 dolphin
20	4/6*	1°25'N.	156°52'W.	960	42 (1)	4.4	-	-	10	1	8	
21	4/8*	10 mi. E. of N.E. Pt.		990	18 (2)	1.8	-	-	2	-	9	2 wahoo
22	4/9*	1°10'N.	156°41'W.	990	25 (2)	2.5	-	-	8	1	12	
23	4/10	1°05'N.	156°33'W.	957	11 (1)	1.1	-	-	1	-	20	
24	4/11*	1°38'N.	157°39'W.	990	76 (8)	7.7	-	1	5	-	17	
25	4/12	1°37'N.	157°47'W.	900	58 (19)	6.4	-	-	4	1	17	1 sunfish
26	4/13*	1°33'N.	158°03'W.	885	37 (3)	4.2	-	3	11	1	9	
27	4/14	1°30'N.	157°41'W.	908	62 (7)	6.8	-	-	1	-	11	
28	4/15*	1°28'N.	157°33'W.	990	58 (6)	5.8	-	-	6	1	6	
29	4/16	1°10'N.	157°33'W.	935	48 (7)	5.1	1	1	7	-	9	
30	4/17	1°20'N.	157°22'W.	990	22	2.2	3	-	-	2	8	
31	4/18	20 mi. W. of London		933	40 (7)	4.3	1	-	1	-	16	1 lancet fish
32	4/19*	1°58'N.	157°48'W.	750	32 (2)	4.3	-	-	-	-	12	1 wahoo
33	4/20	8 mi. W. of Christmas I.		937	55 (15)	5.9	-	-	-	1	13	
34	4/21*	2°04'N.	157°57'W.	990	33 (2)	3.3	-	1	-	-	13	
35	4/22*	1°30'N.	157°37'W.	990	48 (3)	4.8	1	-	-	3	7	
36	4/24	10 mi. S. of S.W. Pt.		934	63 (3)	6.7	-	1	-	1	8	

* Indicates days no count of hooks was maintained.

1/ Numbers in parentheses are shark-damaged fish and are included in the adjacent daily catch.

Table 4.--Summary of fishing localities and catches on 15-hook gear, North American cruise 2 (cont'd)

Sta.	Date	Noon position		Number of hooks	Total catch							
					Yellowfin		Number of fish					
		Latitude	Longitude		Number	Per 100 h.	Big-eye	Alba-core	Skip-jack	Marlin	Shark	Miscellaneous
37	4/25*	12 mi. S.W. of S.E. Pt.		990	66 (6)	6.7	-	-	-	2	9	
38	4/26	15 mi. S. of S.W. Pt.		884	36 (3)	4.1	-	-	-	-	9	
39	4/27	1°44'N.	156°23'W.	725	24 (5)	3.3	-	1	-	-	7	
40	4/28*	1°40'N.	155°09'W.	750	17 (2)	2.3	-	-	-	-	9	
Total				35,965	1,730 (253)	187.9	8	11	77	41	513	
Average					43.2 (6.3)	4.7	0.2	0.3	1.9	1.0	12.8	

* Indicates days no count of hooks was maintained.

Table 5.--Summary of fishing localities and catches on 15-hook gear (from log maintained by Lars Jangaard), Alrita cruise 2

Sta.	Date	Noon position		Estimated number of hooks	Total catch							
					Yellowfin		Number of fish					
		Latitude	Longitude		Number	Per 100 h.	Big-eye	Alba-core	Skip-jack	Marlin	Shark	Miscellaneous
1	3/18	4 mi. S. of Palmyra I.		660	40 (14)[1/]	6.1	3	-	-	1	30	1 wahoo
2	3/19	5°07'N.	161°50'W.	750	8 (2)	1.1	3	-	-	-	6	1 wahoo
3	3/20	4°18'N.	160°10'W.	675	8	1.2	-	-	2	-	8	
4	3/21	2°55'N.	158°54'W.	900	12 (1)	1.3	-	-	5	-	10	
5	3/22	2°15'N.	158°00'W.	900	31 (1)	3.4	-	3	-	-	13	
6	3/23	2°04'N.	157°35'W.	900	12 (1)	1.3	-	1	-	1	20	
7	3/24	1°58'N.	157°08'W.	900	66 (3)	7.3	-	3	-	1	10	
8	3/25	1°56'N.	157°16'W.	975	33 (1)	3.4	-	1	-	4	6	
9	3/26	1°56'N.	157°00'W.	1,110	91 (10)	8.2	-	-	1	2	8	
10	3/27	1°43'N.	157°00'W.	1,050	88 (2)	8.4	-	-	-	1	11	
11	3/28	1°46'N.	157°00'W.	1,050	29 (1)	2.8	-	-	-	3	10	
12	3/29	1°36'N.	156°35'W.	1,050	38 (7)	3.6	-	-	-	1	9	
13	3/30	1°21'N.	157°10'W.	1,050	52 (2)	5.0	-	-	1	-	7	
14	3/31	1°05'N.	157°17'W.	1,050	52 (3)	5.0	-	-	-	-	9	
15	4/1	1°01'N.	157°51'W.	1,050	35 (10)	3.3	-	-	-	-	18	
16	4/2	1°19'N.	157°04'W.	900	24 (2)	2.7	-	1	2	-	3	1 broadbill
17	4/3	1°26'N.	157°50'W.	975	4 (3)	0.4	-	-	-	1	3	
18	4/4	1°30'N.	157°16'W.	975	16 (3)	1.6	1	-	1	-	13	
19	4/5	1°45'N.	157°00'W.	975	30 (8)	3.1	-	-	-	-	16	
20	4/6	1°18'N.	156°55'W.	900	20 (6)	2.2	-	-	10	1	6	
Total				18,795	689 (80)	71.4	7	9	22	16	216	
Average					34.4 (4.0)	3.6	0.4	0.4	1.1	0.8	10.8	

1/ Numbers in parentheses are shark-damaged fish and are included in the adjacent daily catch.

Table 6.--Summary of fishing localities and catches on 6-hook gear, Charles H. Gilbert cruise 15

Sta.	Date	Noon position		Number of hooks	Total catch							
					Yellowfin		Number of fish					
		Latitude	Longitude		Number	Per 100 h.	Big-eye	Alba-core	Skip-jack	Marlin	Shark	Miscellaneous
1	2/19	32°19'N.	119°25'W.	114	-	-	-	-	-	-	9	
3	2/20	30°06'N.	119°43'W.	120	-	-	-	-	-	-	10	
5	2/21	27°54'N.	120°11'W.	180	-	-	-	-	-	-	58	
7*	2/22	25°58'N.	119°58'W.	180	-	-	-	-	-	-	2	3 opah
9*	2/23	23°54'N.	119°45'W.	180	-	-	-	-	-	-	-	1 opah
11*	2/24	21°47'N.	119°50'W.	180	-	-	-	-	-	-	1	4 opah
13*	2/25	19°47'N.	119°42'W.	179	-	-	-	-	-	-	-	1 dolphin
15*	3/3	08°59'N.	110°09'W.	180	1 (1)[1/]	0.6	-	-	-	2	7	1 dolphin
17*	3/4	07°20'N.	110°20'W.	180	1	0.6	-	-	1	1	5	2 sailfish
18*	3/5	05°04'N.	110°37'W.	178	4 (2)	2.2	2	-	-	-	14	1 sting ray
20*	3/6	03°44'N.	110°17'W.	171	7 (2)	4.1	4	-	-	-	3	
22*	3/7	02°26'N.	110°26'W.	179	-	-	-	-	-	-	3	4 lancet fish
24*	3/8	00°48'N.	110°55'W.	179	6	3.4	-	-	-	-	1	2 lancet fish
26*	3/9	00°59'S.	111°28'W.	150	10 (2)	6.7	-	-	-	-	2	
28*	3/10	03°22'S.	112°10'W.	149	1	0.7	1	-	-	-	-	
30*	3/11	05°17'S.	113°11'W.	150	-	-	-	-	1	-	1	
32*	3/12	07°08'S.	114°20'W.	142	1	0.7	19	-	-	-	-	
34	3/13	08°58'S.	114°48'W.	149	1	0.7	1	-	-	-	-	
36	3/15	09°20'S.	120°53'W.	150	1	0.7	3	1	-	1	-	
38	3/18	09°01'S.	131°23'W.	148	-	-	2	-	-	2	-	1 shortnosed spearfish
54	4/9	07°12'S.	155°16'W.	180	-	-	-	-	-	1	2	
56	4/10	05°34'S.	155°13'W.	179	4	2.2	-	1	-	-	1	
58	4/11	04°04'S.	155°21'W.	180	2	1.1	3	-	-	1	2	
60	4/12	02°56'S.	155°11'W.	178	-	-	2	1	-	-	2	
62	4/13	01°19'S.	155°08'W.	179	6	3.4	-	-	1	-	1	2 unident. tuna, 1 blackfish[2/]
64	4/14	00°25'N.	155°07'W.	176	9 (2)	5.1	-	-	-	1	2	
66	4/15	01°58'N.	155°16'W.	180	3	1.7	-	-	-	1	3	
68	4/16	01°48'N.	156°38'W.	179	11 (1)	6.1	-	-	-	-	3	
70	4/17	02°03'N.	157°48'W.	176	9 (2)	5.1	-	-	-	-	1	1 wahoo
71	4/20	02°55'N.	155°55'W.	179	7 (1)	3.9	-	-	2	-	4	
73	4/21	04°37'N.	155°05'W.	179	4 (1)	2.2	-	-	-	1	7	
75	4/22	06°03'N.	155°02'W.	180	3 (2)	1.7	1	-	-	-	4	
Total				5,383	91 (16)	52.9	38	3	5	11	148	
Average					2.8 (0.5)	1.6	1.2	0.1	0.2	0.3	4.6	

* Stations at which 1- and 10-fathom float lines were used.

1/ Numbers in parentheses are shark-damaged fish and are included in the adjacent daily catch. 2/ Globicephala sp.

Table 7.--Summary of fishing localities and catches on 11-hook gear, Charles H. Gilbert cruise 15

Sta.[1/]	Number of hooks	Total catch							
		Yellowfin		Number of fish					
		Number	Per 100 h.	Big-eye	Alba-core	Skip-jack	Marlin	Shark	Miscellaneous
1	220	-	-	-	-	-	-	14	
3	220	-	-	-	-	-	-	17	
5	329	-	-	-	-	-	-	122	
7*	330	-	-	-	-	-	-	3	3 opah
9*	329	-	-	-	-	-	-	3	2 opah
11*	328	-	-	-	-	-	-	3	2 opah, 1 dolphin
13*	330	-	-	-	-	-	-	2	2 dolphin
15*	330	-	-	1	-	-	1	15	1 sailfish
17*	330	1	0.3	2	-	-	-	7	1 sailfish, 1 lancet fish, 1 wahoo
18*	325	12 (3)[2/]	3.7	5	-	-	2	14	
20*	327	17 (6)	5.2	1	-	-	1	6	
22*	329	-	-	1	-	-	-	7	5 lancet fish
24*	327	13 (1)	4.0	-	-	-	-	2	2 lancet fish
26*	275	7	2.5	-	-	-	1	4	
28*	275	-	-	3	-	-	2	1	1 wahoo
30*	275	1	0.4	2	-	5	-	2	
32*	266	-	-	19	-	1	2	1	1 sting ray
34	273	-	-	-	-	-	-	-	
36	270	2 (1)	0.7	3	1	-	1	-	
38	274	-	-	1	1	-	1	-	
54	330	1	0.3	-	-	1	1	1	
56	329	1	0.3	-	1	1	-	1	1 wahoo
58	328	3	0.9	-	1	-	-	4	1 wahoo
60	326	1	0.3	-	2	-	-	1	
62	330	6	1.8	-	1	-	-	4	1 unidentified tuna
64	326	9	2.8	-	-	-	-	3	
66	328	3	0.9	-	1	1	-	4	1 sunfish
68	327	12	3.7	-	1	1	1	2	
70	314	24 (7)	7.6	-	1	2	-	7	
71	325	11	3.4	-	-	-	1	2	
73	319	1 (1)	0.3	1	-	1	-	4	
75	329	2	0.6	1	-	-	1	5	
Total	9,873	127 (19)	39.7	40	10	13	15	261	
Average		4.0 (0.6)	1.2	1.2	0.3	0.4	0.5	8.2	

* Stations at which 1- and 10-fathom float lines were used.

[1/] Dates and positions of these stations given in table 6.

[2/] Numbers in parentheses are shark-damaged fish and are included in the adjacent daily catch.

Table 8.--Summary of fishing localities and catches on steel gear, John R. Manning cruise 20

Sta.	Date	Noon position		Number of hooks	Total catch							
					Yellowfin		Number of fish					
		Latitude	Longitude		Number	Per 100 h.	Big-eye	Alba-core	Skip-jack	Marlin	Shark	Miscellaneous
1	5/17	5°58.0'N.	162°52.5'W.	323	6	1.8	-	-	-	-	4	
2	5/18	6°02.0'N.	162°27.5'W.	327	1	0.3	-	-	-	1	1	
4	5/19	6°07.5'N.	162°12.5'W.	323	1	0.3	5	-	-	-	4	
5	5/20	5°49.4'N.	161°36.4'W.	330	1 (1)[1/]	0.3	-	-	-	-	5	1 lancet fish
6	5/21	5°57.5'N.	161°11.0'W.	330	-	-	1	-	-	1	5	
8	5/22	5°26.5'N.	161°36.7'W.	326	-	-	-	-	-	-	2	
10	5/23	4°55.0'N.	161°19.0'W.	321	3	0.9	-	-	-	1	3	1 wahoo, 1 lancet fish
12	5/24	4°56.0'N.	160°32.0'W.	312	6 (3)	1.9	1	-	-	-	13	
13	5/25	4°45.3'N.	160°11.0'W.	320	13 (2)	4.1	-	-	-	-	24	
15	5/26	4°52.0'N.	159°35.0'W.	216	2	0.9	1	-	-	-	5	
17	5/27	4°17.0'N.	160°27.5'W.	215	1	0.5	-	-	-	-	1	1 broadbill
19	5/28	4°02.0'N.	159°34.2'W.	214	1	0.4	-	-	-	1	1	
21	5/30	3°58.5'N.	159°04.1'W.	214	25 (6)	11.7	1	-	-	-	3	
23	5/31	4°07.9'N.	158°20.5'W.	221	-	-	1	-	-	-	1	
25	6/1	3°04.1'N.	159°12.3'W.	219	3	1.4	-	2	-	-	2	
27	6/2	2°29.0'N.	158°21.9'W.	214	3	1.4	-	1	1	-	1	1 barracuda, 1 lancet fish
29	6/3	1°43.0'N.	158°27.5'W.	218	3	1.4	-	-	-	-	8	
31	6/4	2°03.1'N.	157°39.5'W.	207	14 (7)	6.8	-	-	-	-	10	
33	6/7	1°52.0'N.	156°47.8'W.	215	5 (1)	2.3	-	-	1	-	3	
35	6/8	2°01.4'N.	157°09.0'W.	213	14 (3)	6.6	-	-	-	-	1	
36	6/9	1°47.0'N.	158°15.7'W.	211	3 (1)	1.4	-	-	-	-	3	
38	6/10	0°50.5'N.	158°52.6'W.	210	3	1.4	-	-	-	-	14	
40	6/11	0°26.0'S.	158°56.9'W.	211	3	1.4	1	-	-	-	10	
42	6/12	0°13.5'S.	160°00.5'W.	197	13 (3)	6.6	-	-	-	-	17	1 wahoo
43	6/13	0°17.9'S.	160°16.0'W.	216	-	-	-	-	-	1	5	
45	6/14	0°13.2'S.	160°02.2'W.	217	4 (2)	1.8	-	-	-	-	11	
46	6/15	0°29.5'S.	160°19.2'W.	212	4	1.9	-	1	-	-	1	
Total				6,752	132 (29)	57.5	11	4	2	5	162	
Average					4.9 (1.1)	2.1	0.4	0.1	0.1	0.2	6	

[1/] Numbers in parentheses are shark-damaged fish and are included in the adjacent daily catch.

Table 9.--Summary of fishing localities and catches on 11-hook cotton gear, John R. Manning cruise 20

Sta.[1]	Number of hooks	Total catch							
		Yellowfin		Number of fish					
		Number	Per 100 h.	Big-eye	Alba-core	Skip-jack	Marlin	Shark	Miscellaneous
1	328	2 (1)[2]	0.6	-	-	-	-	2	1 lancet fish
2	321	12 (5)	3.7	-	-	1	1	17	
4	330	-	-	2	-	-	-	4	
5	272	-	-	-	-	-	-	1	2 barracuda
6	323	-	-	-	-	-	1	5	1 lancet fish, 1 leather-back turtle[3]
8	329	1	0.3	2	-	-	-	3	
10	325	4	1.2	-	-	-	-	-	1 wahoo
12	329	-	-	-	-	-	-	7	1 lancet fish
13	318	16 (10)	5.0	-	-	-	1	28	
15	438	3	0.7	-	-	-	-	8	1 wahoo, 1 lancet fish
17	433	29 (6)	6.7	-	-	-	-	8	
19	421	58 (23)	13.8	1	-	-	1	21	
21	327	26	8.0	-	-	-	-	9	
23	325	1	0.3	-	-	1	-	7	1 lancet fish
25	326	4	1.2	1	-	-	-	2	
27	328	2	0.6	-	-	-	-	2	
29	325	5 (2)	1.5	-	-	4	-	11	
31	322	10 (2)	3.1	-	-	-	-	14	
33	328	2 (1)	0.6	-	1	1	-	5	
35	325	22 (6)	6.8	-	1	-	-	21	
36	329	3 (1)	0.9	-	-	-	1	9	
38	316	23 (4)	7.3	-	-	-	1	12	
40	322	5 (2)	1.6	-	1	-	1	4	
42	328	16 (2)	4.9	-	-	-	-	8	
43	318	29 (8)	9.1	-	-	-	-	25	
45	323	14 (5)	4.3	-	-	-	1	17	
46	303	6	2.0	-	-	-	-	3	
Total	9,012	293 (78)	84.2	6	3	6	8	253	
Average		0.9 (2.9)	3.1	0.2	0.1	0.2	0.3	9.3	

[1] Dates and positions of these stations given in table 8.

[2] Numbers in parentheses are shark-damaged fish and are included in the adjacent daily catch.

[3] *Dermochelys schlegelii* (Garman)

Table 10.--Summary of fishing localities and catches on steel gear, Oceanic and Brothers cruise 1

Brothers[1/]

Sta.	Date	Noon position		Estimated number of hooks	Total catch							
					Yellowfin		Number of fish					
		Latitude	Longitude		Number	Per 100 h.	Big-eye	Alba-core	Skip-jack	Marlin	Shark	Miscellaneous
1	6/3	3°53'N.	159°29'W.	200	10 (8)[2/]	5.0	-	-	-	1	17	
2	6/4	3°55'N.	159°28'W.	300	13 (7)	4.3	-	-	-	-	22	
3	6/5	3°54'N.	159°32'W.	300	15 (6)	5.0	-	-	-	-	14	
4	6/7	1°58'N.	157°37'W.	No data								
5	6/8	2°02'N.	157°33'W.	400	16 (10)	4.0	-	-	-	-	24	
6	6/9	1°58'N.	157°37'W.	400	17 (10)	4.2	-	-	-	-	25	
7	6/11	3°53'N.	159°28'W.	200	21 (5)	10.5	-	-	-	-	6	
8	6/12	3°55'N.	159°28'W.	400	7 (5)	1.8	-	-	-	-	7	
9	6/13	3°58'N.	159°28'W.	400	11 (7)	2.8	-	-	-	-	15	
10	6/14	3°55'N.	159°30'W.	400	7 (3)	1.8	-	-	-	3	10	
Total				3,000	117 (61)	39.4	-	-	-	4	140	
Average					13.0 (6.8)	4.4	-	-	-	0.4	15.6	
Oceanic												
1	6/3	3°55'N.	159°28'W.	279	1	0.4	-	-	-	-	3	
2	6/4	3°50'N.	159°28'W.	460	12 (6)	2.6	-	-	-	1	4	
3	6/5	3°51'N.	159°32'W.	456	3 (1)	0.6	-	-	-	-	7	
4	6/7	2°02'N.	157°35'W.	460	3 (3)	0.6	-	-	-	-	40	
5	6/8	1°56'N.	157°35'W.	378	4	1.0	-	-	-	2	9	
6	6/9	1°54'N.	157°37'W.	475	5 (3)	1.0	-	-	-	-	32	1 wahoo
7	6/11	3°50'N.	159°28'W.	475	5 (2)	1.0	-	-	-	1	10	
8	6/12	4°02'N.	159°25'W.	383	13 (9)	3.4	-	-	-	-	36	
9	6/13	3°55'N.	159°36'W.	482	10 (2)	2.1	2	-	-	-	6	
10	6/14	3°53'N.	159°39'W.	389	3 (1)	0.8	-	-	-	-	4	
Total				4,237	59 (27)	13.5	2	-	-	4	151	
Average					5.9 (2.7)	1.4	0.2	-	-	0.4	15.0	

1/ The data from the Brothers may not be entirely accurate. No detailed record was kept and the daily fishing log was filled out a few days later from memory by the captain of the Brothers.

2/ Numbers in parentheses are shark-damaged fish and are included in the adjacent daily catch.

Table 11.--Summary of fishing localities and catches on steel gear, Commonwealth cruise 1

Sta.	Date	Noon position 1/		Estimated number of hooks	Total catch							
					Yellowfin		Number of fish					
		Latitude	Longitude		Number	Per 100 h.	Big-eye	Alba-core	Skip-jack	Marlin	Shark	Miscellaneous
1	7/26	3°43'N.	159°36'W.	300	3	1.0	-	-	-	-	2	
2	7/28	2°23'N.	158°19'W.	500	5 (1) 2/	1.0	1	-	2	-	1	1 broadbill
3	7/29	1°51'N.	158°05'W.	600	2	0.3	-	-	-	1	10	
4	8/3	1°55'N.	158°10'W.	600	13 (2)	2.2	-	-	-	-	12	
5	8/4	1°54'N.	157°43'W.	600	8 (1)	1.3	2	-	-	-	14	2 dolphin
6	8/5	1°49'N.	157°10'W.	600	15 (3)	2.5	3	-	2	2	9	2 wahoo
7	8/6	1°19'N.	156°47'W.	500	10	2.0	-	1	2	-	8	1 wahoo
8	8/7	1°06'N.	156°27'W.	600	20 (3)	3.3	-	-	1	1	9	
9	8/8	1°05'N.	156°24'W.	200	-	-	-	-	-	-	12	
10	8/9	1°15'N.	156°40'W.	500	10	2.0	1	-	1	1	3	
11	8/11	1°32'N.	156°33'W.	500	13 (5)	2.6	-	-	1	-	7	
Total				5,500	99 (15)	18.2	7	1	9	5	87	
Average					9.1 (1.4)	1.6	0.5	0.1	0.8	0.4	8.2	

1/ Position when first basket was hauled.

2/ Numbers in parentheses are shark-damaged fish and are included in the adjacent daily catch.

Table 12.--Summary of fishing localities and catches on steel gear, Brothers cruise 2

Sta.	Date	Noon positon		Estimated number of hooks	Total catch							
					Yellowfin		Number of fish					
		Latitude	Longitude		Number	Per 100 h.	Big-eye	Alba-core	Skip-jack	Marlin	Shark	Miscellaneous
1	7/26	3°58'N.	159°30'W.	500	5 (1)[1/]	1.0	1	-	1	1	5	
2	7/28	3°15'N.	159°30'W.	500	12	2.4	-	-	1	-	7	
3	7/29	3°19'N.	159°09'W.	500	1 (1)	0.2	-	-	-	-	2	
4	8/3	15 mi. W. of London		200	-	-	-	-	-	-	3	
5	8/5	6 mi. W. of London		500	2 (1)	0.4	-	-	-	-	8	
6	8/6	15 mi. W. of London		500	9 (1)	1.8	-	-	-	-	6	1 sailfish
7	8/9	14 mi. S.W. of Bridges Pt.		400	7 (3)	1.8	-	-	-	-	13	
8	8/11	42 mi. S.E. of Fanning I.		100	-	-	-	-	-	-	1	
Total				3,200	36 (7)	7.6	1	-	2	1	45	
Average					4.5 (0.9)	1.0	0.1	-	0.2	0.1	5.6	

[1/] Numbers in parentheses are shark-damaged fish and are included in the adjacent daily catch.

Table 13.--Summary of fishing localities and catches, Oceanic cruise 2

Sta.	Date	Noon position		Estimated number of hooks	Total catch							
					Yellowfin		Number of fish					
		Latitude	Longitude		Number	Per 100 h.	Big-eye	Albacore	Skipjack	Marlin	Shark	Miscellaneous
1	7/26	9 mi. W. xS. of Fanning I.		600	7 (1)[1/]	1.2	-	-	1	-	7	
2	7/28	2°20'N.	158°14'W.	600	10	1.7	-	-	1	-	4	
3	7/29	30 mi. W. xN. of Christmas I.		600	11 (1)	1.8	-	-	1	-	8	2 dolphin
4	8/3	6 mi. N.W. of S.W. Pt.		600	11 (4)	1.8	-	-	-	-	22	
5	8/5	10 mi. W. of Christmas I.		600	20 (2)	3.3	-	-	-	-	12	
6	8/6	10 mi. W. xS. of Christmas I.		600	11 (4)	1.8	-	-	-	-	8	
7	8/7	3 mi. S.W. of Christmas I.		500	1 (1)	0.2	-	-	-	-	7	
8	8/8	6 mi. S.W. of Christmas I.		500	17 (2)	3.4	1	-	-	-	2	
9	8/9	8 mi. S. of Christmas I.		500	12	2.4	-	-	-	-	8	
10	8/11	50 mi. S.E. of Fanning I.		500	4	0.8	-	-	-	-	7	
Total				5,600	104 (15)	18.4	1	-	3	-	85	
Average					10.4 (1.5)	1.8	0.1	-	0.3	-	8.5	

[1/] Numbers in parentheses are shark-damaged fish and are included in the adjacent daily catch.

Table 14.--Summary of fishing localities and catches on 10-hook gear, Sea Hawk cruise 1

Sta.	Date	Noon position		Estimated number of hooks	Total catch							
					Yellowfin		Number of fish					
		Latitude	Longitude		Number	Per 100 h.	Big-eye	Alba-core	Skip-jack	Marlin	Shark	Miscellaneous
1	10/3	3°45'N.	155°50'W.	500	5 (1)[1/]	1.0	-	-	-	1	37	
2	10/4	2°55'N.	156°12'W.	350	2	0.6	-	-	-	-	12	1 sunfish
3	10/5	40 mi. N. E. of Christmas I.		470	10 (1)	2.1	-	-	-	1	9	
4	10/6	40 mi. N. W. of Christmas I.		380	1	0.3	-	-	1	2	10	
5	10/8	15 mi. N. W. of Christmas I.		500	15 (6)	3.0	-	-	-	2	21	
6	10/9	15 mi. N. W. of Christmas I.		380	1	0.3	-	-	-	1	6	
7	10/10	2°07'N.	157°55'W.	460	9 (2)	2.0	-	-	-	-	9	
8	10/11	2°06'N.	157°25'W.	500	4 (2)	0.8	-	-	-	2	4	
9	10/13	0°50'N.	156°30'W.	500	7	1.4	-	-	-	-	17	
10	10/14	0°25'N.	157°43'W.	500	2	0.4	-	-	-	-	-	
11	10/15	1°56'N.	156°59'W.	500	1	0.2	-	-	-	-	9	
12	10/20	4°00'N.	157°15'W.	500	1	0.2	-	-	2	-	2	
Total				5,540	58 (12)	12.3	-	-	3	9	136	
Average					4.8 (1.0)	1.0	-	-	0.2	0.8	11.3	

[1/] Numbers in parentheses are shark-damaged fish and are included in the adjacent daily catch.

Table 15.--Summary of fishing locations and catches on steel and 11-hook cotton gear, Commonwealth cruise 2

Sta.	Date	Noon position		Estimated number of hooks	Total catch							
					Yellowfin		Number of fish					
		Latitude	Longitude		Number	Per 100 h.	Big-eye	Alba-core	Skip-jack	Marlin	Sharks	Miscellaneous
1*	10/28	1°10'N.	157°19'W.	600	1	0.2	1	-	1	1	14	
2*	10/29	2°14'N.	156°33'W.	600	20 (13)[1/]	3.3	-	-	-	1	17	
3*	10/30	2°30'N.	156°51'W.	300	7 (1)	2.3	-	-	-	-	14	
4	10/31	30mi. N.W. of Christmas I.		400	17 (6)	4.2	-	-	-	-	14	1 wahoo
5	11/1	30mi. N.W. of Christmas I.		480	18 (1)	3.8	-	-	-	-	7	
6	11/2	30mi. N.E. of Christmas I.		496	5	1.0	-	-	-	-	8	
7	11/3	30mi. S.E. of Christmas I.		480	11 (4)	2.3	-	-	-	1	-	
8*	11/4	1°42'N.	156°30'W.	550	12 (7)	2.2	-	-	-	1	14	
9	11/8	2°08'N.	157°49'W.	472	8 (2)	1.7	-	-	-	-	9	
10	11/12	30mi. N.W. of Fanning I.		544	19 (11)	3.5	-	-	-	1	31	
11	11/13	4°13.5'N.	159°15'W.	544	25 (3)	4.6	1	-	-	-	16	
12	11/14	3°33'N.	158°27'W.	540	5 (2)	0.9	-	-	-	2	3	
13	11/15	4°08.4'N.	159°44'W.	544	13 (8)	2.4	-	-	1	3	15	
14	11/16	30mi. N.E. of Fanning I.		400	14 (1)	3.5	-	-	-	-	10	
15	11/22	60mi. S.W. of Palmyra I.		520	3 (1)	0.6	-	-	-	-	19	2 barracuda
Total				7,470	178 (60)	36.5	2	-	2	10	191	
Average					11.9 (4.0)	2.4	0.1	-	0.1	0.7	13.6	

* Stations at which steel gear was fished.

[1/] Numbers in parentheses are shark-damaged fish and are included in the adjacent daily catch.

Table 16.--Yellowfin catch by hook number, North American cruise 1 (see fig. 20 - Appendix)

Sta.	Hook Number															Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
2	-	1	-	-	-	1	2	1	3	1	1	-	-	-	1	11
3	2	1	-	1	2	3	5	4	5	3	2	5	1	-	-	34
5	2	2	3	4	6	3	1	7	7	5	6	2	4	3	1	56
6	3	3	5	6	4	8	5	4	4	3	5	2	2	1	1	56
7	5	3	5	9	6	5	8	8	9	6	6	3	4	5	5	87
8	4	4	2	3	5	-	8	4	2	6	5	2	1	1	2	49
10	1	5	3	5	6	4	5	8	6	4	3	6	4	2	2	64
11	5	3	5	8	7	5	8	3	5	5	2	6	6	4	4	76
18	-	2	1	2	2	3	-	3	2	3	1	-	-	-	-	19
19	2	2	1	4	2	-	8	1	7	4	2	-	-	2	1	36
20	-	-	1	3	5	3	7	4	3	1	2	-	1	-	-	30
22	2	-	3	3	2	1	4	-	2	-	-	2	3	-	-	22
Total	26	26	29	48	47	36	61	47	55	41	35	28	26	18	17	540
%	4.8	4.8	5.4	8.9	8.7	6.7	11.3	8.7	10.2	7.6	6.5	5.2	4.8	3.3	3.1	100

Table 17.--Length frequencies of yellowfin taken on fabric gear on four cruises in the central Pacific (Line Islands), 1954

Fork length (cm.)	Male					Female				
	Manning 20	Gilbert 15*	N. Am. 2	N. Am. 1	Total	Manning 20	Gilbert 15*	N. Am. 2	N. Am. 1	Total
54-55	-	-	-	-	-	-	-	1	-	1
56-57	-	-	-	-	-	-	-	-	-	-
58-59	-	-	-	-	-	-	-	-	-	-
60-61	-	-	-	-	-	-	-	-	-	-
62-63	-	-	-	-	-	-	-	-	-	-
64-65	-	-	-	-	-	-	-	-	-	-
66-67	-	-	-	-	-	-	-	-	-	-
68-69	-	-	-	1	1	-	-	-	-	-
70-71	-	-	-	3	3	-	-	1	5	6
72-73	-	-	-	4	4	-	-	-	3	3
74-75	-	-	1	2	3	-	-	1	-	1
76-77	-	-	2	1	3	-	-	1	-	1
78-79	1	-	2	-	3	-	-	-	1	1
80-81	-	-	2	-	2	-	-	-	-	-
82-83	1	-	3	-	4	-	-	1	-	1
84-85	-	-	3	1	4	-	1	2	-	3
86-87	2	1	1	-	4	-	-	4	-	4
88-89	3	-	1	-	4	2	-	3	-	5
90-91	2	1	-	2	5	1	-	-	2	3
92-93	3	-	3	-	6	5	-	2	-	7
94-95	1	-	2	-	3	-	-	-	1	1
96-97	3	-	1	2	6	2	-	3	1	6
98-99	2	-	3	6	11	2	1	4	-	7
100-101	3	-	3	5	11	5	-	7	3	15
102-103	3	-	6	2	11	4	-	9	6	19
104-105	3	1	6	5	15	1	1	7	11	20
106-107	8	-	1	10	19	2	-	7	11	20

* Stations 54-75 only.

Table 17.--Length frequencies of yellowfin taken on fabric gear on four cruises in the central Pacific (Line Islands), 1954 (cont'd)

Fork length (cm.)	Male					Female				
	Manning 20	Gilbert 15	N. Am. 2	N. Am. 1	Total	Manning 20	Gilbert 15	N. Am. 2	N. Am. 1	Total
108-109	2	-	9	16	27	2	-	3	12	17
110-111	4	-	8	17	29	2	-	3	12	17
112-113	7	-	7	6	20	1	-	5	10	16
114-115	6	-	4	6	16	4	-	4	8	16
116-117	10	-	3	7	20	5	-	6	4	15
118-119	5	-	3	2	10	3	-	2	-	5
120-121	7	-	6	1	14	5	1	-	-	6
122-123	2	1	1	-	4	4	1	3	-	8
124-125	4	1	3	2	10	-	2	5	-	7
126-127	3	-	3	1	7	2	-	2	2	6
128-129	2	1	2	3	8	4	-	2	-	6
130-131	-	2	5	1	8	-	1	5	1	7
132-133	1	2	4	2	9	5	-	7	-	12
134-135	2	1	6	1	10	2	2	6	1	11
136-137	5	-	2	1	8	-	3	13	1	17
138-139	3	1	10	2	16	3	2	11	4	20
140-141	2	2	11	1	16	5	5	29	4	43
142-143	2	1	14	5	22	4	6	29	3	42
144-145	6	1	27	3	37	2	7	27	6	42
146-147	9	8	41	18	76	5	6	35	2	48
148-149	9	7	33	14	63	2	3	20	3	28
150-151	5	4	33	11	53	3	5	24	-	32
152-153	4	5	32	5	46	-	1	7	-	8
154-155	3	1	19	1	24	-	-	10	-	10
156-157	2	3	15	1	21	-	1	8	-	9
158-159	3	6	16	1	26	-	2	3	-	5
160-161	1	3	12	-	16	-	-	-	-	-
162-163	2	4	7	-	13	-	-	-	-	-
164-165	1	2	5	-	8	-	1	-	-	1
166-167	-	-	2	-	2	-	-	-	-	-
168-169	-	1	1	-	2	-	-	-	-	-
170-171	-	-	-	-	-	-	-	-	-	-
Total	147	60	384	172	763	87	52	322	117	578

Table 18.--Results of Japanese commercial longline fishing in the central Pacific during 1954 (data from Nomura 1954-55)

Area	Sta.	Boats	Baskets	Hooks	Average catch per 100 hooks										
					Yellow-fin	Big-eye	Alba-core	Skip-jack	Black marlin	White marlin	Striped marlin	Broad-bill	Sail-fish	Shark	Misc.
						JANUARY									
10°-11°N. 174°W.	17	1	6,120	24,480	0.41	4.04	0.06	-	0.19	-	0.01	0.04	-	-	-
29°-30°N. 179°-170°W.	20	1	5,868	29,340	0.01	1.42	2.34	0.06	-	-	0.04	0.11	-	0.18	-
30°-32°N. 170°-169°W.	18	1	6,230	31,150	-	1.63	0.72	0.31	-	-	0.05	0.12	-	-	0.02
						FEBRUARY									
10°-11°N. 176°-174°W.	18	1	6,480	32,400	0.34	3.10	0.12	-	0.25	0.02	0.01	0.01	-	-	0.02
23°-30°N. 171°-158°W.	28	1	8,720	43,600	0.08	1.14	0.03	0.01	0.10	0.02	0.08	0.11	-	0.03	-
						MARCH									
8°-12°N. 180°-165°W.	103	5	37,000	180,072	0.22	1.90	0.11	-	0.36	-	0.04	0.01	0.01	-	-
0°-11°N. 179°-166°W.	25	1	8,355	41,775	2.22	0.87	0.08	-	0.32	-	0.05	-	0.01	0.20	0.15
						APRIL									
8°-12°N. 179°-164°W.	243	12	89,528	421,344	0.13	2.39	0.06	0.04	0.43	0.01	0.05	0.02	0.02	-	0.10
0°-4°N. 178°-170°W.	85	4	32,335	140,857	3.07	0.50	0.21	0.03	0.40	0.03	0.02	0.01	-	-	-
2°N.-11°S. 177°-169°W.	34	1	13,490	53,960	3.93	0.72	0.57	0.10	0.37	0.05	0.01	0.02	0.01	-	0.02
						MAY									
9°-12°N. 170°W.-180°	27	2	9,805	49,025	0.07	2.57	0.01	0.02	0.78	0.01	-	0.02	-	-	-
5°S.-11°N. 169°-178°W.	20	1	7,200	36,000	1.99	1.43	0.28	0.09	0.43	0.04	0.03	0.01	-	-	-
3°N.-7°S. 155°-169°W.	29	1	12,319	43,704	6.54	0.40	0.59	-	0.38	0.08	0.02	0.02	-	-	-

Table 18.--Results of Japanese commercial longline fishing in the central Pacific during 1954 (data from Nomura 1954-55) (cont'd)

Area	Sta.	Boats	Baskets	Hooks	Average catch per 100 hooks										
					Yellow-fin	Big-eye	Alba-core	Skip-jack	Black marlin	White marlin	Striped marlin	Broad-bill	Sail-fish	Shark	Misc.
						JUNE									
0°-13°N. 157°-177°W.	113	4	45,108	180,096	0.36	2.63	0.01	0.05	0.72	0.01	0.05	0.01	0.02	0.69	0.33
2°N.-(3°S.) 170°-177°W.	49	1	20,050	80,200	3.72	0.21	0.43	0.05	0.22	0.04	0.01	0.01	-	0.18	-
1°-3°N. 157°-165°W.	36	1	14,400	64,800	2.20	0.93	0.19	-	0.40	0.02	-	0.19	-	-	-
						JULY									
6°-11°N. 179°-163°W.	46	1 (2)	17,451	71,253	0.38	2.01	-	-	0.83	-	-	0.01	-	-	0.01
1°-8°N. 179°-155°W.	136	6	52,100	232,345	3.99	0.54	0.11	0.05	0.35	0.03	-	0.01	0.03	0.05	0.03
0°-4°N. 166°-150°W.	66	2	24,360	121,800	5.80	0.26	0.22	0.02	0.21	0.03	0.03	-	-	-	0.16
1°-7°S. 178°-160°W.	57	2	22,620	100,740	2.78	0.58	0.11	0.22	0.37	0.02	0.01	0.02	0.05	0.26	0.04
						AUGUST									
6°-8°N. 136°-135°W.	25	1	10,223	51,115	2.45	2.63	-	-	0.30	0.05	0.03	0.01	-	-	0.02
6°-11°N. 174°-171°W.	18	1	6,660	26,640	0.57	1.55	-	-	1.31	0.01	-	-	-	-	0.38
0°-12° N. 180°-167°W.	37	1	14,275	57,100	2.43	0.91	0.12	-	0.65	0.03	0.01	-	0.01	0.20	0.03
2°S.-10°N. 162°-151°W.	34	1	13,764	53,950	1.87	1.75	0.01	-	0.99	0.02	-	0.01	-	0.64	0.01
						SEPTEMBER									
5°-11° N. 176°-172°W.	83	4	30,800	154,000	0.42	1.20	0.01	0.05	0.83	0.01	-	0.01	0.05	-	0.05
37°-39°N. 180°-177°W.	20	1	4,230	20,960	0.04	2.17	0.52	-	0.01	-	0.07	0.04	-	0.13	0.01
						OCTOBER									
4°-12°N. 178°-157°W.	84	4	31,329	146,012	0.25	1.12	0.01	-	0.50	0.01	0.01	-	0.01	0.01	-

Table 18.--Results of Japanese commercial longline fishing in the central Pacific during 1954 (data from Nomura 1954-55) (cont'd)

Area	Sta.	Boats	Baskets	Hooks	Average catch per 100 hooks										
					Yellow-fin	Big-eye	Alba-core	Skip-jack	Black marlin	White marlin	Striped marlin	Broad-bill	Sail-fish	Shark	Misc.
					OCTOBER (cont'd)										
24°-32°N. 178°-168°W.	96	4	34,047	144,869	0.08	1.32	0.03	-	0.09	-	0.07	0.01	-	0.04	0.01
27°-39°N. 180°-167°W.	97	4	33,887	156,645	0.03	1.24	1.76	-	0.03	-	0.05	0.05	-	0.05	0.01
					NOVEMBER										
5°-9°N. 145°-133°W.	149	5	55,789	250,774	0.53	3.45	0.01	0.20	0.41	0.02	0.05	0.04	0.05	0.20	-
25°-32°N. 180°-163°W.	200	10	63,460	300,730	0.16	1.85	0.13	-	0.06	-	0.08	0.02	-	0.07	0.04
0°-16°S. 175°-176°W.	26	1	9,576	47,880	1.10	0.14	1.65	-	0.77	0.01	0.06	0.01	0.02	-	-
					DECEMBER										
5°-10°N. 142°-130°W.	99	3	37,924	163,166	0.96	3.73	-	0.06	0.24	0.01	0.10	0.03	0.05	0.12	0.02
7°-8°N. 148°-140°W.	14	1	5,695	23,480	0.22	2.95	-	-	0.51	0.01	-	0.04	0.04	-	-
28°-34°N. 180°-167°W.	203	9	65,592	316,753	-	1.95	0.91	-	0.01	-	0.06	0.12	-	0.25	0.02
25°-34°N. 170°-164°W.	134	6	43,075	195,455	0.11	2.11	0.15	-	0.03	-	0.04	0.03	-	0.11	0.01
4°-11°N. 175°-171°W.	14	1	4,692	23,460	0.43	1.37	-	-	0.14	0.01	0.02	-	0.01	-	-
19°-22°S. 174°-171°W.	19	1	6,485	32,425	1.07	0.09	6.00	0.04	0.79	0.02	0.43	0.02	0.02	-	0.30

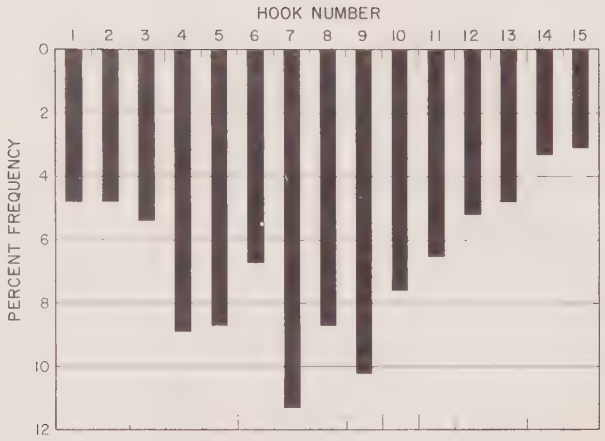


Figure 20.--Percentage of yellowfin catch by hook number (hence relative depth) on North American cruise 1, illustrating the prevalence of higher catch rates on the deeper hooks.

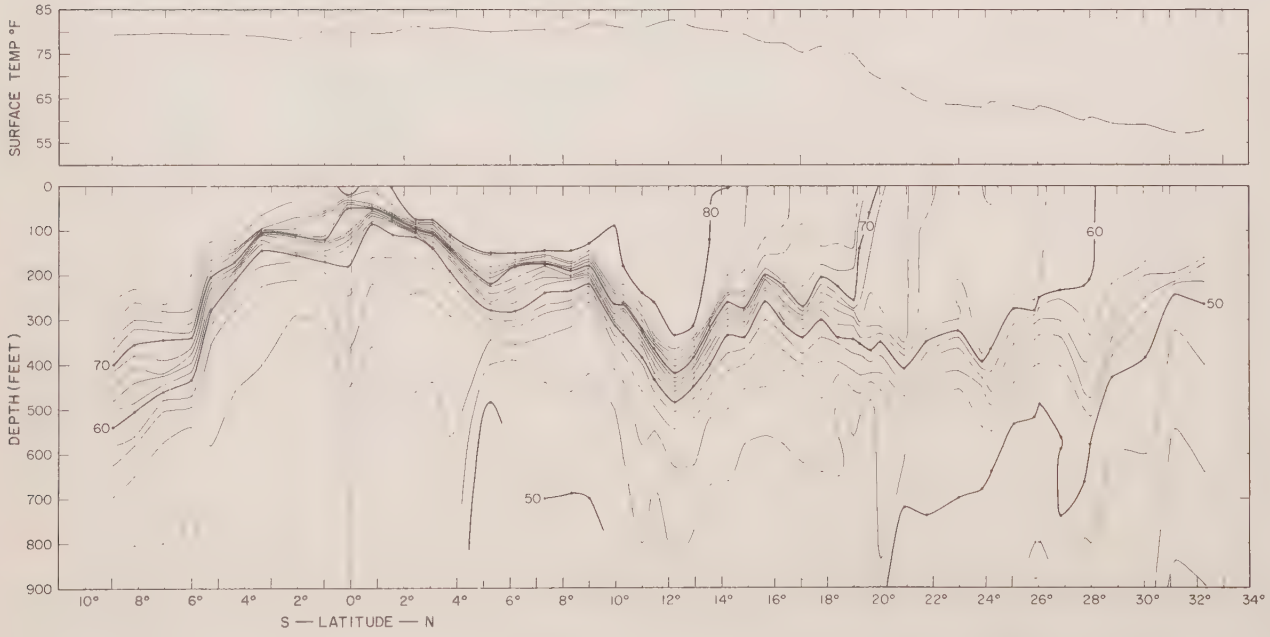


Figure 21.--Surface temperature and vertical temperature section along 120°W. and 109°W. longitude, February-March (Charles H. Gilbert cruise 15). Upper panel--surface temperatures as read at each bathythermograph lowering. Lower panel--temperature section based on bathythermograph lowerings; isotherms at 2°F. intervals, depth of lowering shown by horizontal dashes.

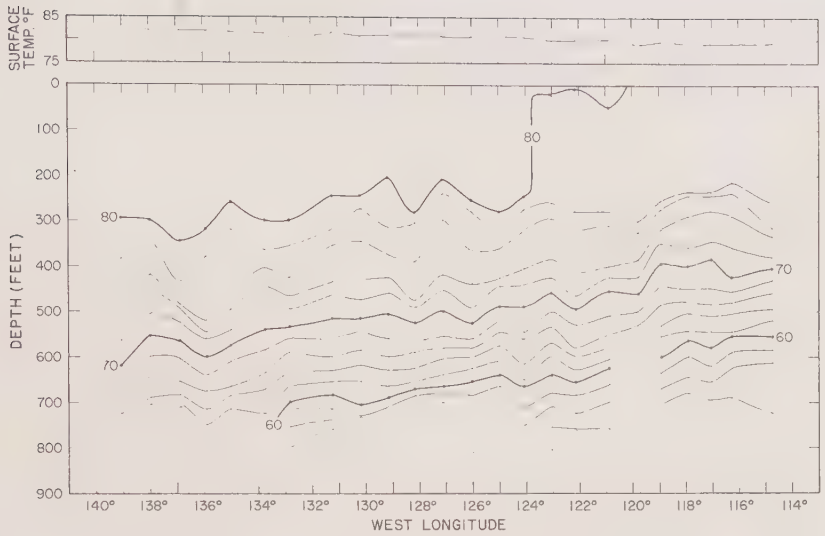


Figure 22.--Surface temperature and vertical temperature section along 9°S. latitude from 115°W. longitude to the Marquesas Islands, March (Charles H. Gilbert cruise 15). Upper panel--surface temperatures as read at each bathythermograph lowering. Lower panel--temperature section based on bathythermograph lowering; isotherms at 2°F. intervals, depth of lowering shown by horizontal dashes.

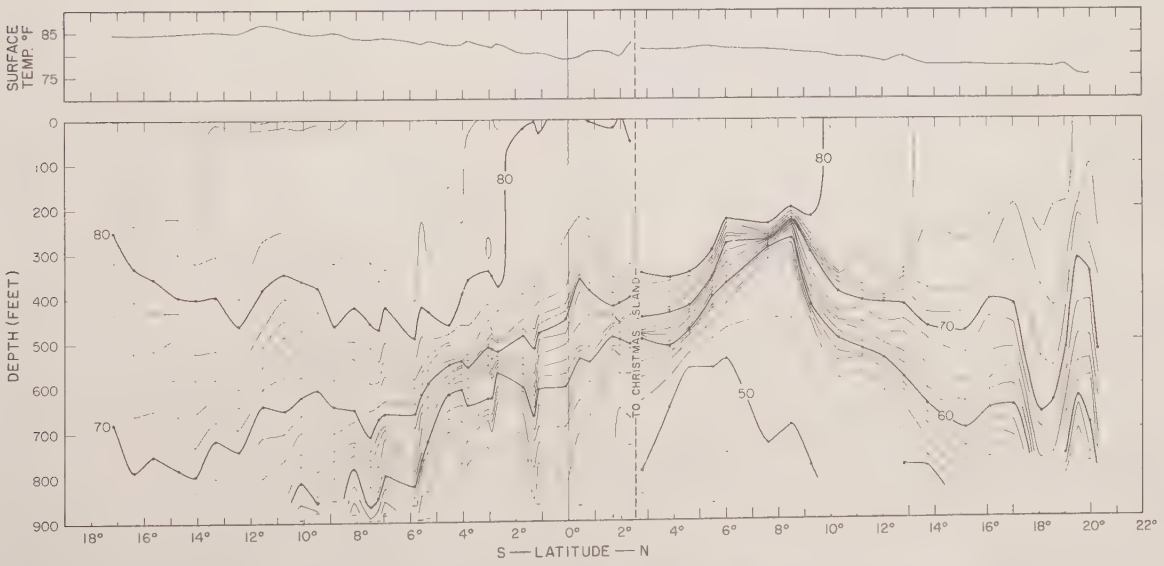


Figure 23.--Surface temperature and vertical temperature section along a south-north section between 149°W. and 157°W. longitude, April (Charles H. Gilbert cruise 15). Upper panel--surface temperatures as read at each bathythermograph lowering. Lower panel--temperature section based on bathythermograph lowering; isotherms at 2°F. intervals, depth of lowering shown by horizontal dashes.

COMPARATIVE STUDY OF FOOD OF BIGEYE AND YELLOWFIN TUNA IN THE CENTRAL PACIFIC

BY JOSEPH E. KING AND ISAAC I. IKEHARA

FISHERY BULLETIN 108
From Fishery Bulletin of the Fish and Wildlife Service
VOLUME 57

UNITED STATES DEPARTMENT OF THE INTERIOR, Fred A. Seaton, *Secretary*
FISH AND WILDLIFE SERVICE, John L. Farley, *Director*

ABSTRACT

Stomachs of 166 bigeye tuna (*Parathunnus sibi*) and 439 yellowfin tuna (*Neothunnus macropterus*), captured in the central Pacific by longline fishing, were analyzed quantitatively to determine whether there were differences in the food which might help explain differences in the horizontal and vertical distribution of the tunas. This study provides the first comprehensive report on the food of the bigeye tuna.

Representatives of 48 fish families and 11 invertebrate orders were found among the stomach contents of the yellowfin, as compared with 36 fish families and 9 invertebrate orders for the bigeye. Food items of major importance to both species were pomfret (*Collybus drachme*), snake mackerel (*Gempylus serpens*), and squid of the families Ommastrephidae and Loliginidae. Notable differences were the complete lack of stomatopods in the food of bigeye, whereas they were common in yellowfin, and the insignificance of juvenile tunas in the food of bigeye, as compared with their prominence in the food of yellowfin.

In both tunas, the smaller individuals consumed a greater proportion by volume of crustaceans and fish and a lesser proportion of mollusks than the larger size group. In both tunas there was a tendency for the volume of stomach contents to increase with depth of capture, but there was no marked variation in food composition over the range of depth sampled. In the bigeye the volume of stomach contents varied directly with the longline catch rate, while in the yellowfin there was little change in volume of stomach contents even with a marked change in catch rate.

Despite these differences, the foods of yellowfin and bigeye were remarkably similar. When occupying the same general area, the two species were found to have essentially the same feeding habits.

UNITED STATES DEPARTMENT OF THE INTERIOR, Fred A. Seaton, *Secretary*
FISH AND WILDLIFE SERVICE, John L. Farley, *Director*

COMPARATIVE STUDY OF FOOD OF BIGEYE AND YELLOWFIN TUNA IN THE CENTRAL PACIFIC

By Joseph E. King, and Isaac I. Ikehara

FISHERY BULLETIN 108
From Fishery Bulletin of the Fish and Wildlife Service
VOLUME 57

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1956

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.
Price 30 cents

CONTENTS

	Page
Source of materials	62
Methods	63
Results	66
Variation in food with size of tuna	66
Variation in food with depth of capture	67
Variation in food with distance from land	68
Variation with season and longitude	69
Variation with current system	73
Other variations in volume of stomach contents	77
Summary and conclusions	79
Literature cited	80
Appendix	82

COMPARATIVE STUDY OF FOOD OF BIGEYE AND YELLOWFIN TUNA IN THE CENTRAL PACIFIC

By JOSEPH E. KING and ISAAC I. IKEHARA, *Fishery Research Biologists*

The predominant species of tuna captured on longline-fishing surveys of the Fish and Wildlife Service's Pacific Oceanic Fishery Investigations (POFI) are the yellowfin, *Neothunnus macropterus* (Temminck and Schlegel), and the bigeye, *Parathunnus sibi* (Temminck and Schlegel), with a catch ratio of about 5 to 1 in favor of the yellowfin. These are large tunas, the yellowfin occasionally reaching a weight of 200 pounds and the bigeye a weight of 300 pounds in the tropical Pacific. The two species have a marked superficial resemblance in general body shape and coloration and are not always differentiated in the commercial catch.

Murphy and Shomura (1953a, 1953b), in discussing results of experimental longline fishing conducted by POFI, point out interesting differences in the distribution of these two species. In the tropical Pacific, the bigeye have been taken in greatest numbers north of latitude 5° N. The best catches of yellowfin, on the other hand, have been made in the general region of the Equator, sometimes to the north when the area is under the influence of southeast tradewinds, and sometimes to the south when the northeast trades are dominant. This shift in abundance that appears to be related to changes in the prevailing winds can now be explained, at least partially, from our knowledge of the ocean currents and their effect on the basic food supply (Cromwell 1953).[1] Although the peaks in abundance do not correspond exactly, the general area of high yellowfin catch is also the area of greatest zooplankton abundance (King 1954). The horizontal distribution of the bigeye, however, does not seem to conform to the general pattern that the most fish are found where food is most abundant.

There is also some evidence of difference in the vertical distribution of yellowfin and bigeye. While the results are rather variable, there have been indications on certain POFI cruises to the equatorial area that the best catches of bigeye came from greater depths than those of the yellowfin (Murphy and Shomura 1953b). In Hawaiian waters the bigeye occurs in greatest numbers during the winter months from October to May, whereas the yellowfin is most abundant from May to September (Otsu 1954). Brock (1949) points out that the Hawaiian longline fishermen try to increase the catch of bigeye after the yellowfin season by lengthening the hook lines in order to fish deeper. Also, unlike the yellowfin, the bigeye—at least the adults—are rarely taken by surface-fishing methods. Nakamura (1949) states that the bigeye is thought to occur at the deepest levels of any of the tunas. It appears that the bigeye prefers somewhat colder water than does the yellowfin, or perhaps the two species have different feeding habits or food preferences which influence their distribution.

The purposes of this study are to describe the food of bigeye tuna in the central Pacific, to compare the foods of bigeye and yellowfin tuna[2] captured at about the same time and place, to determine whether differences occur which are associated with the horizontal and vertical distribution of these fish, and to obtain information on food preferences of each fish which may be useful to the commercial fishery. The experimental fishing carried out by POFI has provided collections of bigeye and yellowfin stomachs which are essentially alike in respect of time and area and which were obtained with standardized fishing methods. Therefore, we believe the resulting data should provide reliable comparisons of the food of these fish because these several variables have been controlled.

There is an extensive literature, reviewed previously by Reintjes and King (1953), dealing with the food of yellowfin, whereas there are only a very

[1] Also a manuscript by O. E. Sette: Nourishment of central Pacific stocks of tuna by the equatorial current system (Proceedings of the 8th Pacific Science Congress).

[2] The food of yellowfin was previously described by Reintjes and King (1953).

few references pertaining specifically to the food of bigeye. Suyehiro (1942) describes this species as a very voracious fish and lists the following items as appearing in its food: amphipods, shrimp, cuttlefish, squid, sardines, sauries, bonitos, needle fish, and a viper fish. In the report of the South Seas Tuna Fishery Investigations for 1950 (Kanagawa et al. 1951), the food of 27 bigeye is shown to include the following: 7 squid, 1 octopod, 3 decapod Crustacea, 1 fan fish, 15 needle fish, 1 file fish, 6 pomfret, and 4 lantern fish. This suggests that the bigeye, like many other tunas, has a varied diet.

A large number of the tuna stomachs reported on here were examined by John W. Reintjes, Sueto Murai, and T. J. Roseberry, former employees of POFI. We appreciate their services in a difficult and generally disagreeable task. We are grateful to other staff members of POFI for assistance in handling these large fish aboard the vessels and in removing and preserving the stomachs.

SOURCE OF MATERIALS

This report is based on examination of 439 yellowfin and 166 bigeye stomachs collected on 11 cruises of Fish and Wildlife Service vessels during the years 1950 to 1953 (table 1). The yellowfin data include 125 stomachs collected in 1950 and 1951 and previously reported on by Reintjes and King (1953). These collections and the additional 314 yellowfin stomachs obtained in 1952 and 1953 were obtained at the same stations, or near the same stations, as furnished the bigeye stomachs included in this report. The sampling area (fig. 1) extended along the Equator between latitudes 119° W. and 180° and approximately from latitude 17° N. to latitude 14° S. at its greatest width.

The tuna were captured by longline at depths of about 150 to 500 feet. This method of fishing, as practiced by POFI, has been reviewed by Murphy and Shomura (1953a); the design and construction of the gear was described by Niska (1953).

Only fish caught 25 miles or more from land are considered in this study; therefore local differences due to reef faunas should be reduced to a minimum. The sampled fish varied widely in size, from 87 to 172 cm. fork length for the yellowfin, and from 77 to 196 cm. fork length for the bigeye (fig. 2). Weights of fish given in this paper were

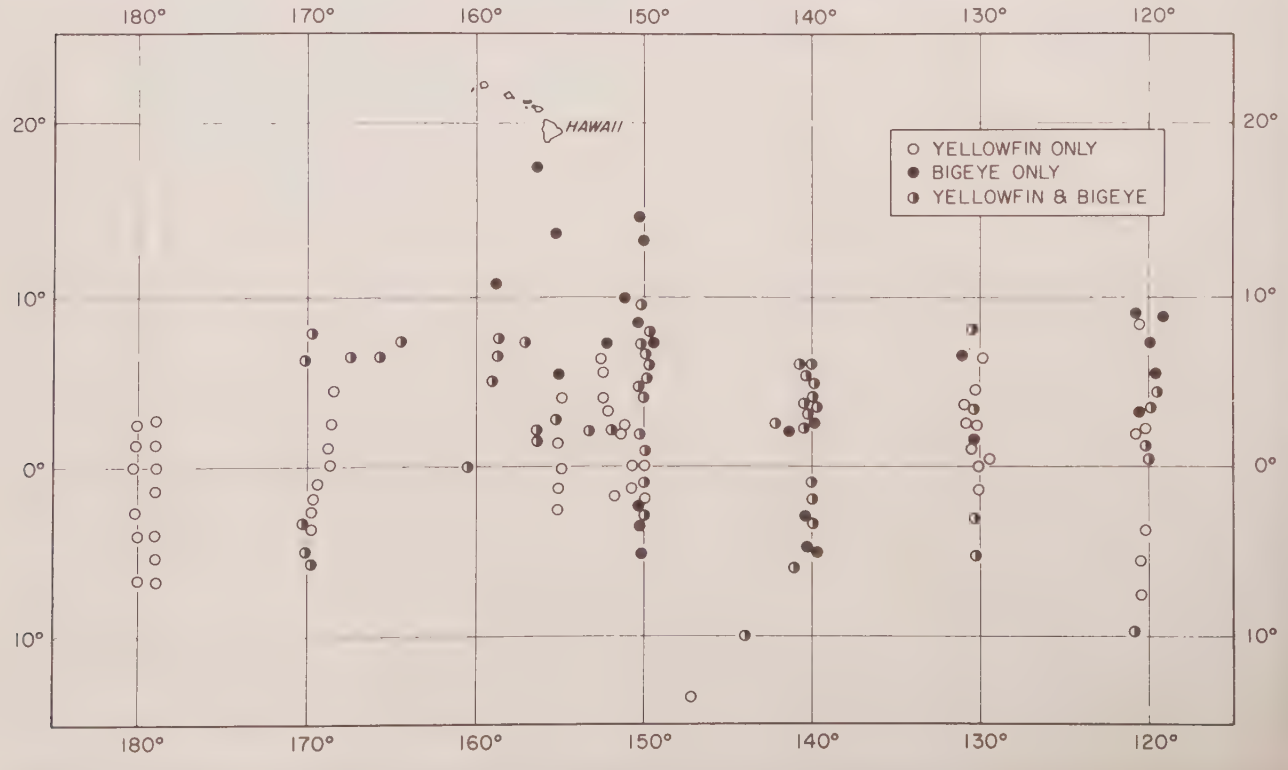


FIGURE 1.—Locations of the stomach collections of yellowfin and bigeye tuna captured by experimental longline fishing in the central Pacific, 1950–53.

TABLE 1.—*Distribution of yellowfin and bigeye stomachs collected from the central Pacific, identified by vessel, cruise, time of year, and locality*

Vessel	Cruise No.—	Period	Sampling area		Yellowfin			Bigeye		
			Range of longitude (W.)	Range of latitude	Number captured	Number of stomachs examined	Percent of catch sampled	Number captured	Number of stomachs examined	Percent of catch sampled
Hugh M. Smith	7	Oct.–Nov. 1950	157°–167°	11° N–0°	132	[1] 106	80	22	14	64
Hugh M. Smith	11	Aug.–Sept. 1951	150°–156°	15° N–4° S	457	[2] 153	34	93	36	39
John R. Manning	11	Jan.–Mar. 1952	155°–180°	5° N–7° S	210	59	28	30	6	20
Charles H. Gilbert	1	May–June 1952	119°–130°	9° N–1° S	72	44	61	43	17	40
Cavalieri	1	June–July 1952	140°	6° N–5° N	42	7	17	11	2	18
Cavalieri	2	Aug.–Sept. 1952	140°–142°	6° N.–2° N	720	19	3	60	13	22
John R. Manning	12	Aug.–Sept. 1952	140°–150°	7° N.–5° S	146	1	1	28	5	18
John R. Manning	13	Oct.–Nov. 1952	151°–170°	17° N.–5° S	135	55	41	29	10	34
Hugh M. Smith	18	Oct.–Nov. 1952	120°–131°	9° N.–10° S	60	40	67	50	17	34
John R. Manning	14	Jan.–Mar. 1953	140°–150°	4° N.–14° S	106	69	65	19	19	100
John R. Manning	15	Apr.–June 1953	150°–170°	10° N.–6° S	197	20	10	46	27	59

[1] Of this number, only 38 (29 percent of the catch) were considered comparable in respect to time and place to the bigeye collections and were included in this report.

[2] Of this number, only 87 (19 percent of the catch) were included in this report for the same reason as above.

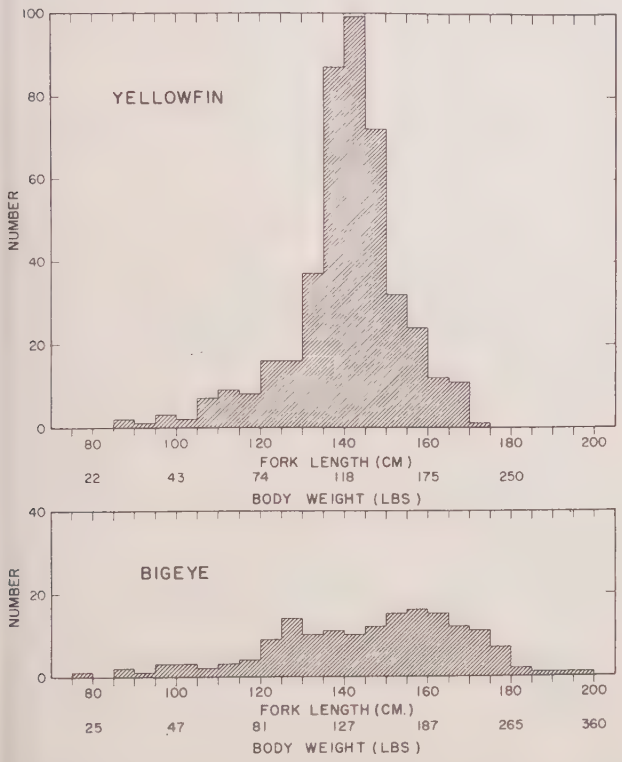


FIGURE 2.—Length-frequency distribution of yellowfin and bigeye tuna from which stomachs were collected.

derived from length measurements converted by means of length-weight tables provided in the POFI Scientific Field Manual (unpublished).

METHODS

At sea, the stomach was removed as soon as possible after the fish was captured, placed with any regurgitated material in an unbleached-muslin bag, and preserved in 10-percent formalin. A label bearing date, species name, fork length, fishing method, hook number, bait used, name of observer, vessel, and cruise number was placed with each stomach. Tuna landed with their stomachs everted were not sampled.

The stomach was removed by one of the following methods: (1) The abdominal cavity was opened by a longitudinal midventral incision, the small intestine was severed posterior to the pyloric valve, and the stomach was freed by cutting through the esophagus; or (2) the gill membrane was slit along the line of attachment with the cleithrum posterior to the fourth gill arch, the viscera was pulled out, and the stomach was removed by cutting through the small intestine and esophagus.

In the laboratory, the stomachs were soaked in fresh water for a period of 16 to 24 hours to remove excess formalin. Each stomach was then slit open, and the contents were carefully removed and separated into groups according to kind of organism. Identifications were made as completely as was practicable, and the number of each species or group of organisms present was recorded. Each species or group was measured volumetrically by the displacement of water in a graduated cylinder of appropriate size. Bait used to capture the tuna was omitted from this analysis. The methods and literature used in the identification of the food organisms were essentially the same as that employed by Reintjes and King (1953) and will not be reviewed here. Berg's (1947) system of classification and nomenclature was primarily used for the family names of the forage fishes.

A detailed list of the food organisms found in the tuna stomachs is presented in the appendix (table 11). For each kind or group of organisms there are shown (1) the total number of such organisms, (2) the number of stomachs in which they occurred, (3) the percentage of occurrence, (4) the total aggregate volume of each food element, and (5) the percentage of total volume.

Regardless of the method or methods of analysis used, there are many uncontrollable variables inherent in food studies which detract from the precision of the results. It is our belief, however, that for a fish with a generalized diet, such as that of the tuna, any of the commonly used methods of evaluation will give substantially the same results if a sufficiently large number of specimens are examined. In reporting the results of our studies on tuna food we use both the percentage-of-occurrence and the percentage-of-volume measurements (as described by Reintjes and King 1953) and the average volume of food per stomach. The food items that rank high in number, volume, and frequency of occurrence are most likely to be important foods.

No attempt has been made to apply statistical tests of significance to the data. It is likely that the variates used—volume of food per stomach, percentage of occurrence, and percentage of total volume of the organism—are not distributed normally and that the means are correlated with the variances or standard deviations. To apply meaningful tests of significance, transformation of the data would be necessary. Moreover, several of the comparisons that will be made involve two-way or three-way classification of the data. Even if suitable transformations were derived, the application of advanced analysis of variance techniques would be hampered by unequal subclass numbers.

Furthermore, it appears that in both yellowfin and bigeye there is an increase in mean volume of food per stomach with increase in size of fish,

FIGURE 3.—Examples of types of food commonly found in stomachs of yellowfin and bigeye tunas: Left to right: pomfret (1), truncated sunfish (1), snake mackerel (1), lancet fish (1), shrimps (3), viper fish (3), hatchet fish (3), euphausids (8), juvenile stomatopods (3), crab megalopa (12), squid (3), and paper nautilus (1).

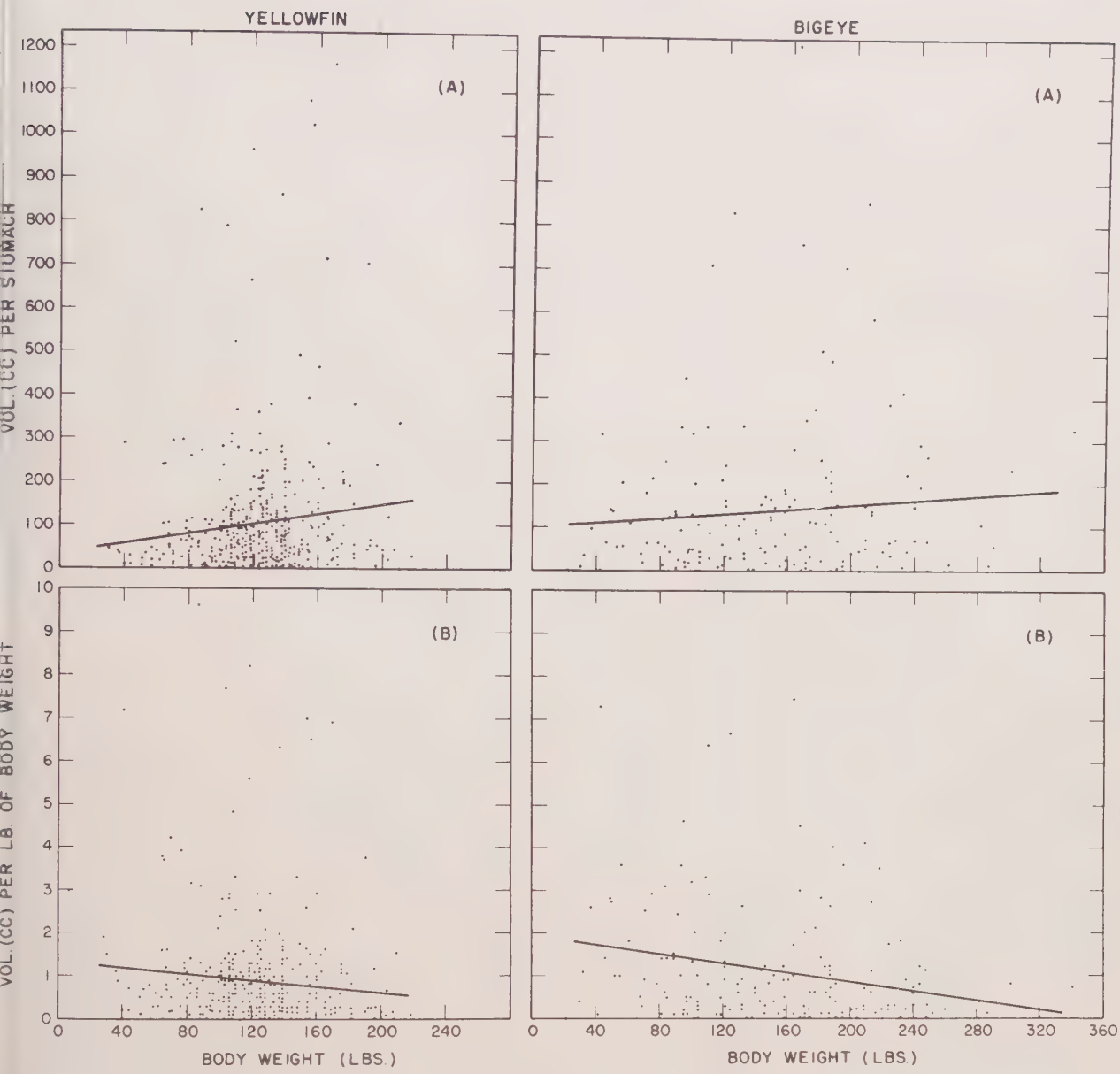


FIGURE 4.—Regressions of (A) food volume per stomach and (B) food volume per unit body weight on total body weight for 439 yellowfin and 166 bigeye captured on longlines.

and there is also a decrease in average stomach content per unit of body weight (cc./lb.) with increase in size of fish. The least-squares trend lines shown in figure 4 (there is no *a priori* reason for assuming rectilinearity) indicate the need for covariance methods of statistical analysis, again after suitable transformations. Finally we must point out the great variability of the data as illustrated by the wide scatter of points about the trend lines. This great variability reduces the opportunity of demonstrating statistically significant differences, particularly when the data are analyzed in subgroups which contain few specimens in each.

Because of the difficulties outlined above, in the following sections we have tabulated average values and have discussed differences and trends without attempting to appraise their statistical significance. Consequently, the inferences that we make must be regarded as suggestions only. They may form the bases for hypotheses which can be tested more stringently in the future.

RESULTS

The food of both the yellowfin and the bigeye was primarily fish, of great variety, and squid (table 11, Appendix). Other mollusks, such as the argonauts and octopods, and crustaceans were of minor importance.[3] Figure 5 illustrates the percentage of occurrence of the major food items. Figure 6 shows the percentage of aggregate total volume of each major food element, which indicates its relative importance by bulk.

Representatives of 48 fish families and 11 invertebrate orders were found among the stomach contents of the yellowfin, as compared with 36 fish families and 9 invertebrate orders for the bigeye.[4] Despite this great variety in the food, only a few items were of primary importance to either species. For both the yellowfin and the bigeye, those food elements ranking high in number, volume, and frequency of occurrence were squid, of the families Ommastrephidae and Loliginidae, and among the fish the pomfret (*Collybus drachme*) and snake mackerel (*Gempylus serpens*) were important. Certain fishes, such as the tunas (Thunnidae) and the sun fishes (Molidae), were relatively important in volume but ranked low in number and frequency of occurrence, indicating that they are only occasionally utilized. Crustacea of the order Stomatopoda, prominant in number in the food of yellowfin, were completely lacking from the bigeye stomachs. The young of other tunas, especially skipjack, formed a much more important part of the yellowfin diet than that of the bigeye. In the following sections of this report we shall try to describe the major differences and similarities in the foods of these two species of tuna as related to such factors as size of the tuna, area and depth of capture, season, and features of the equatorial-current system.

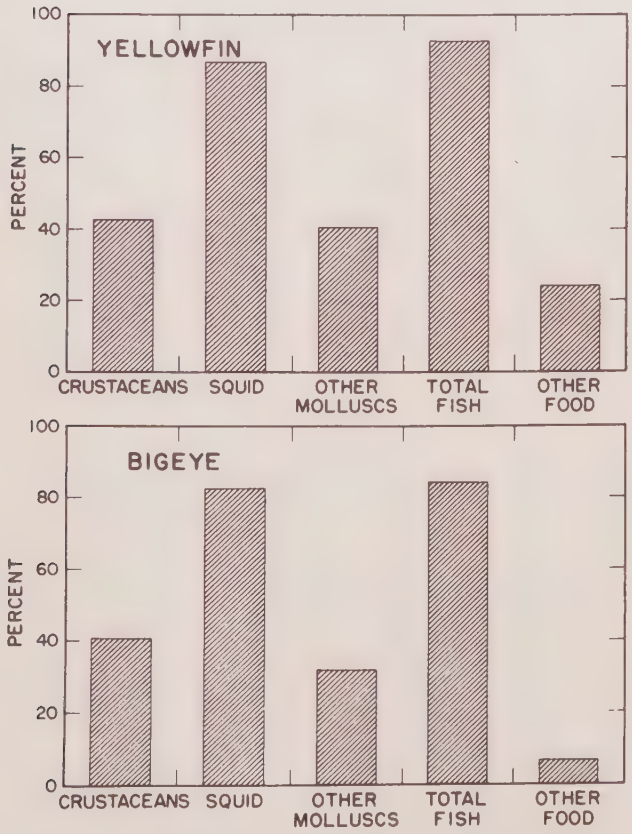


FIGURE 5.—Percentage of occurrence of the major food elements.

Variation in Food with Size of Tuna

In general, for both yellowfin and bigeye, there was an increase in food volume per stomach with an increase in size of the tuna (fig. 4). With the hope of minimizing the effects of this factor, in our examination of differences in the food specifically related to size of tuna we have split the data for both species into two size groups, (1) those less than 140 cm.[5] and (2) those 140 cm. and over, in fork length (table 2). This provided for each species two groups of fish roughly equal in number. In the yellowfin the larger size group contained 29 percent more food per stomach, and in the bigeye it contained 16 percent more. The ratios of stomach content to body weight are almost identical for the two species (table 2). Although Crustacea make up a very small percentage of the food of these large, deep-swimming fish, in both species the smaller specimens consumed greater amounts of such organisms as crab larvae, shrimp, and amphipods. In both species, the larger specimens consumed less fish and more mollusks—as percentage of total volume—than did the smaller size group; this was particularly true for the bigeye. The per-

[3] Among the results of this study, not referred to elsewhere in the report but perhaps worthy of mention, were observations on the number of stomach parasites. Among the bigeye, 26 percent of the stomachs examined were infested with nematodes and 32 percent with trematodes. The infestation was somewhat less among the yellowfin, being 16 percent for nematodes and 26 percent for trematodes.

[4] The greater variety in the food of the yellowfin as compared with the bigeye is due, we believe, simply to the fact that more than twice as many yellowfin stomachs were examined.

[5] A 140-cm. yellowfin from the equatorial Pacific weighs approximately 118 pounds, while a 140-cm. bigeye weighs approximately 127 pounds.

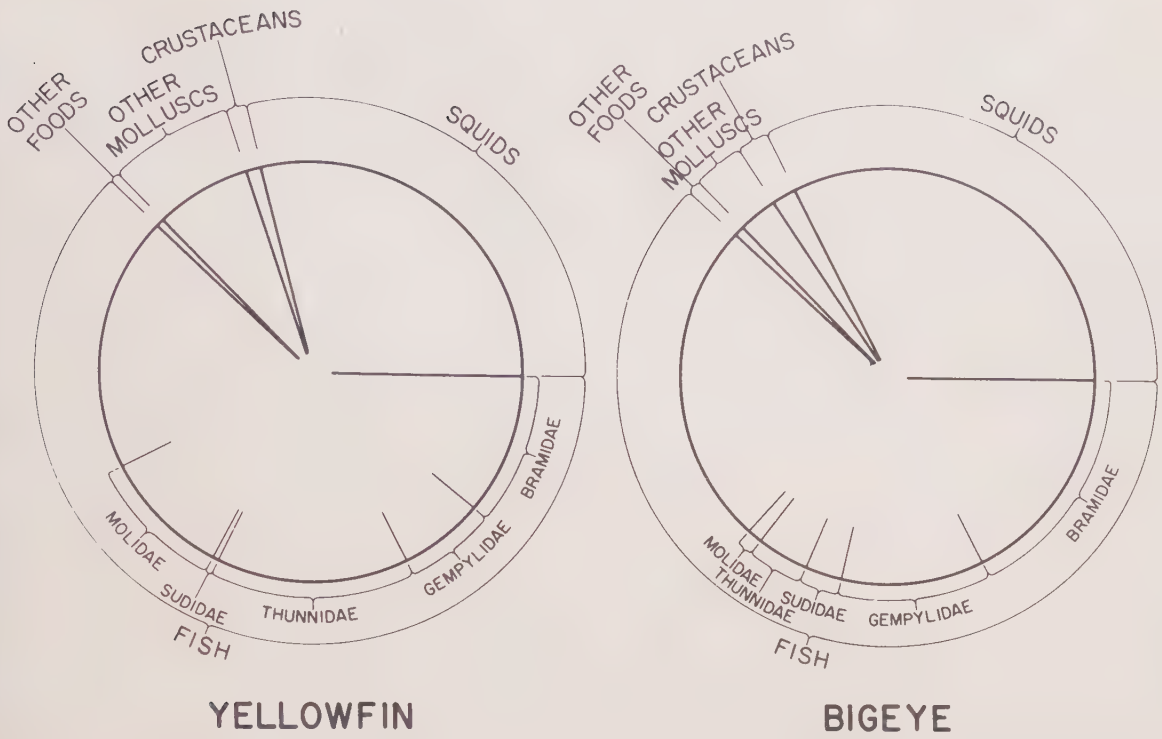


FIGURE 6.—Comparative importance, in volume, of the major food elements.

centage by occurrence and percentage by volume for the fish families prominent in the diet exhibited little variation with the size of the tuna.

Variation in Food with Depth of Capture

Figure 7 is a diagram of one unit (a basket) of POFI longline gear, showing the arrangement of hook-bearing dropper lines and the general lay of the line with respect to the surface. Although an attempt is made to set the line at each station in a standard fashion, with an average distance between buoys of about 900 feet, the actual depth of fishing is quite variable depending upon the amount of sag in the main line, which is greatly influenced by wind and current conditions.

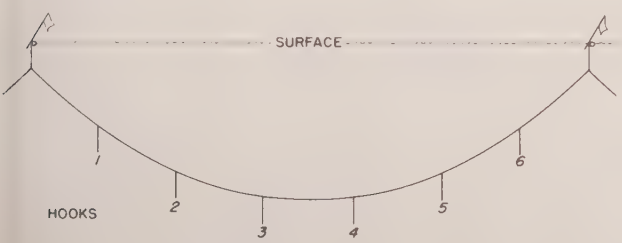


FIGURE 7.—Arrangement of a unit (basket) of POFI standard longline gear showing the float lines, main line, hook-bearing dropper lines, and the general lay of the line with respect to the surface.

388734 O—56——2

Murphy and Shomura (1953a) have calculated that the maximum possible depth for hooks 1 and 6, with a 900-foot buoy interval, is 310 feet; for hooks 2 and 5, it is 450 feet; and for hooks 3 and 4, it is 530 feet. These maximum depths are seldom achieved, however, because of the relatively strong surface currents generally prevailing in this region. The minimum depths are even more uncertain; therefore it is difficult to define a depth range for each of the hooks. We postulate that hooks 1 and 6 may fish at depths of 150 to 300 feet, hooks 2 and 5 at depths of 250 to 400 feet, and hooks 3 and 4 at depths of 300 to 500 feet. Despite this variation and the uncertainties involved, it is worthwhile, without attempting to designate actual fishing depths, to make comparisons between the shallow (hooks 1 and 6), intermediate (hooks 2 and 5), and deep (hooks 3 and 4) levels of capture with respect to differences in stomach contents. Because of the rather slight differences in composition of the food associated with the size of the tuna, the two size groups ($<$140 cm. and $>$140 cm.) were combined for this study.

Table 3 shows the variation in composition of stomach contents with depth of capture; the variation in the two general categories, squid and fish,

TABLE 2.—*Variation in volume and composition of stomach contents of yellowfin and bigeye tuna, by size groups*

Food organisms	Average volume (cc.) per stomach in fish—		Percentage of occurrence in fish—		Percentage of total volume in fish—	
	Less than 140 cm., fork length	140 cm., and larger, fork length	Less than 140 cm., fork length	140 cm., and larger, fork length	Less than 140 cm., fork length	140 cm., and larger, fork length
Crustaceans:						
Yellowfin	1.5	0.9	45.2	41.0	1.7	0.8
Bigeye	2.8	2.0	38.1	41.7	2.3	1.4
Squids:						
Yellowfin	24.8	33.3	89.4	85.3	28.6	29.5
Bigeye	32.1	51.4	81.0	83.5	26.2	36.3
Other mollusks:						
Yellowfin	3.3	10.4	29.8	48.6	3.8	9.2
Bigeye	1.6	5.7	28.6	34.0	1.3	4.0
Fish (total):						
Yellowfin	56.6	67.7	90.4	94.8	65.2	60.0
Bigeye	85.8	82.4	84.1	84.5	70.1	58.2
Bramidae:						
Yellowfin	9.1	12.9	53.7	65.7	10.4	11.4
Bigeye	33.3	17.3	36.5	31.1	27.2	12.2
Gempylidae:						
Yellowfin	6.0	7.3	24.5	37.4	6.9	6.5
Bigeye	19.2	12.5	42.9	34.0	15.7	8.8
Thunnidae:						
Yellowfin	10.0	18.6	6.9	9.2	11.5	16.5
Bigeye	0.3	8.6	1.6	3.9	0.3	6.0
Sudidae:						
Yellowfin	0.4	0.5	9.0	5.2	0.5	0.4
Bigeye	1.7	5.2	15.9	17.5	1.4	3.7
Molidae:						
Yellowfin	13.4	7.2	3.7	2.0	15.4	6.4
Bigeye	2.0	1.4	3.2	1.0	1.6	1.0
Other foods:						
Yellowfin	0.6	0.6	23.9	24.3	0.7	0.5
Bigeye	0.1	0.2	1.6	9.7	0.0	0.1
All foods:						
Yellowfin	86.9	112.9				
Bigeye	122.4	141.6				
Number of stomachs examined:						
Yellowfin	188	251				
Bigeye	63	103				
Average fork length (cm.):						
Yellowfin	117	149				
Bigeye	122	160				
Average weight, lbs.:						
Yellowfin	69	142				
Bigeye	85	187				
Average volume (cc.) of food per lb. of body weight:						
Yellowfin	1.3	0.8				
Bigeye	1.4	0.8				

is illustrated in figure 8. For the yellowfin, there is an increase in average volume of stomach contents with increasing depth of capture; for the bigeye, the largest average volume was found at the intermediate depth, with the deep-caught fish ranking second. For both species, the most consistent feature was the low average food volume for the shallow-caught fish.

In the yellowfin, the increase with depth is largely due to a higher consumption of fish, particularly juvenile tunas (Thunnidae) and sunfishes (Molidae), at the intermediate and deep levels; the squid are utilized about equally at all three depths. In the bigeye taken on the deeper hooks, there is also greater utilization of fish, particularly pomfrets (Bramidae) and snake mackerels (Gempylidae), with squid decreasing in relative importance with depth but varying irregularly in absolute volume. Despite these rather minor differences, there is no marked variation in composition of stomach contents over this range of depth (estimated at 150 to 500 feet), which may be evidence that both the forage organisms and the tuna range throughout this water layer.

Variation in Food with Distance from Land

In the routine processing of the stomach data, the records were classified according to the distance of the place of capture from the nearest emergent land. An arbitrary scale (0–24 miles, 25–99 miles, 100–399 miles, and 400 miles and more) was used as in the previous study (Reintjes and King 1953). No bigeye stomachs were collected at 0–24 miles, and few (eight) were collected in the 25–99 mile interval; therefore, the data do not provide the desired information on differences in the food related to this feature. There was some indication that the consumption of squid and pomferts by the bigeye increased in an offshore direction, as compared with their uniform utilization by the

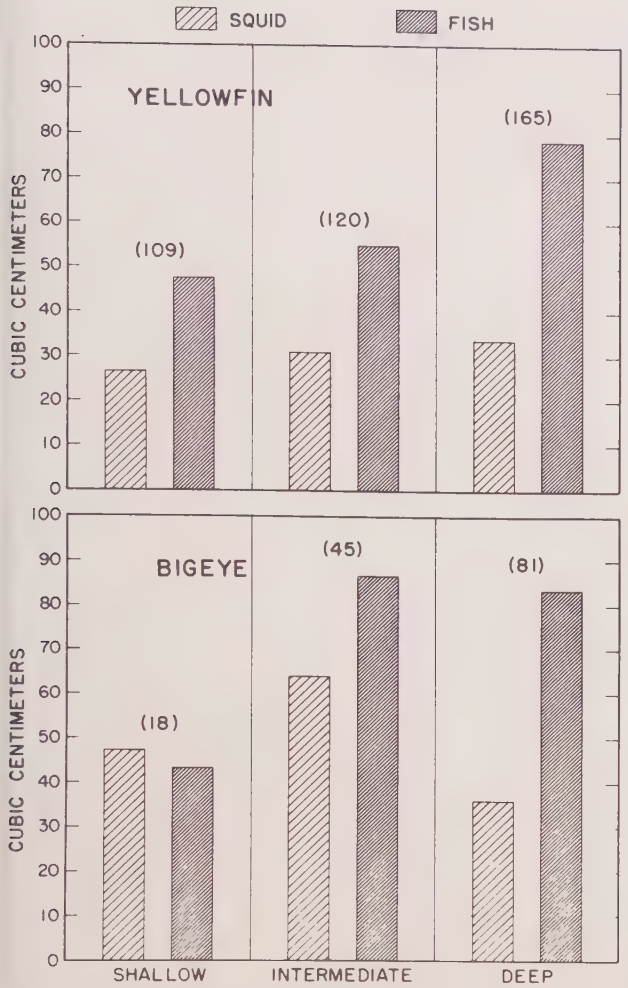


FIGURE 8.—Variation in the major food categories (total fish and squid) as related to the depth at which the tuna were captured. Number of stomachs is shown in parentheses.

yellowfin (table 4), and in the bigeye the average food volume increased with greater distance from land while in the yellowfin the volume varied irregularly.

Variation with Season and Longitude

To examine differences related to time of sampling, the various cruises were grouped into four seasonal periods, as indicated in table 5. For both species the largest average volume of food occurred in the April–July period, with October-November averaging the lowest in the yellowfin and August-September the lowest in the bigeye. If we consider the average volume per stomach of the major food elements, we find that, in our samples of both tunas, fish were consumed in greatest amount during April-July and in least amount during August-September (fig. 9 and table 5). The average volumes of squid and the major fish families represented in the food did not vary in parallel fashion for the bigeye and yellowfin.

When the data from the various cruises are combined with regard to longitude but without regard to time of year, we obtain the results presented in table 6, with the variation in availability

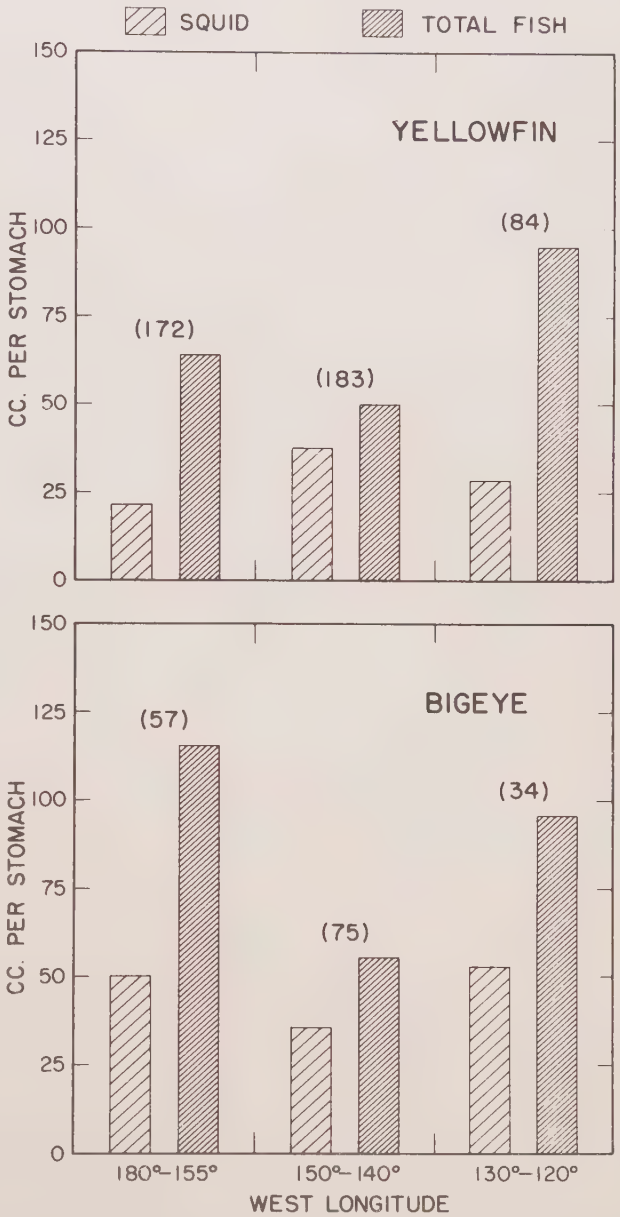


FIGURE 9.—Variation in the major foods as related to time of year that the tuna were captured. Number of stomachs is shown in parentheses.

TABLE 3.—*Variation in volume and composition of stomach contents with depth of capture of yellowfin and bigeye tuna*

Food organisms	Average volume (cc.) per stomach			Percentage of occurrence			Percentage of total volume		
	Shallow	Intermediate	Deep	Shallow	Intermediate	Deep	Shallow	Intermediate	Deep
Crustaceans:									
Yellowfin	1.8	0.7	1.1	39.4	44.2	46.7	2.0	0.8	0.9
Bigeye	0.7	1.4	3.2	33.3	35.6	46.9	0.7	0.9	2.5
Squids:									
Yellowfin	26.6	30.7	33.7	84.4	90.0	90.3	30.2	33.3	27.7
Bigeye	47.2	63.9	36.0	72.2	84.4	83.9	51.4	41.7	27.7
Other mollusks:									
Yellowfin	11.8	5.4	7.4	47.7	49.2	37.0	13.5	5.8	6.1
Bigeye	0.8	0.9	6.9	33.3	17.8	40.7	0.8	0.6	5.3
Fish (total):									
Yellowfin	47.4	54.9	78.6	91.7	91.7	93.9	53.8	59.5	64.6
Bigeye	43.2	86.7	83.7	72.2	86.7	85.2	47.0	56.5	64.5
Bramidae:									
Yellowfin	9.0	10.8	13.4	53.2	64.2	66.7	10.2	11.7	11.0
Bigeye	5.3	22.5	21.1	27.8	26.7	35.8	5.8	14.7	16.3
Gempylidae:									
Yellowfin	5.3	6.7	9.0	33.9	35.0	33.9	6.0	7.3	7.4
Bigeye	4.4	22.7	14.5	33.3	42.2	39.5	4.8	14.8	11.2
Thunnidae:									
Yellowfin	10.6	14.4	22.2	9.2	9.2	9.1	12.0	15.6	18.2
Bigeye	0.0	0.5	2.5	0.0	2.2	2.5	0.0	0.3	1.9
Sudidae:									
Yellowfin	1.0	0.4	0.3	11.9	4.2	7.3	1.2	0.4	0.2
Bigeye	5.0	6.0	3.5	11.1	17.8	22.2	5.5	3.9	2.7
Molidae:									
Yellowfin	1.8	4.4	12.8	1.8	1.7	2.4	2.0	4.8	10.5
Bigeye	0.0	3.4	1.4	0.0	4.4	1.2	0.0	2.2	1.1
Other foods:									
Yellowfin	0.5	0.4	0.9	27.5	23.3	27.3	0.5	0.5	0.8
Bigeye	0.0	0.3	0.1	5.5	8.8	7.4	0.0	0.2	0.0
All foods:									
Yellowfin	88.1	92.2	121.7						
Bigeye	91.9	153.3	129.9						
Number of stomachs examined:									
Yellowfin	109	120	165						
Bigeye	18	45	81						
Average fork length (cm.):									
Yellowfin	141	140	142						
Bigeye	152	148	142						
Average weight (lbs.):									
Yellowfin	120	118	122						
Bigeye	162	148	133						
Average volume (cc.) food per pound of body weight:									
Yellowfin	0.7	0.8	1.0						
Bigeye	0.6	1.0	1.0						

TABLE 4.—*Variation in volume and composition of stomach contents with distance of place of capture from nearest emergent land*

Food organisms	Average volume (cc.) per stomach			Percentage by occurrence			Percentage of total volume		
	25–99 miles	100–399 miles	400 mi. and over	25–99 miles	100–399 miles	400 mi. and over	25–99 miles	100–399 miles	400 mi. and over
Crustaceans:									
Yellowfin	1.2	1.8	0.4	53.3	52.7	7.7	1.1	2.2	0.4
Bigeye	3.7	1.9	2.5	75.0	42.8	35.8	8.2	1.7	1.6
Squids:									
Yellowfin	30.7	24.2	34.8	90.0	89.6	84.1	27.1	29.0	29.6
Bigeye	9.8	17.9	64.2	75.0	76.2	87.4	21.7	15.4	41.8
Other mollusks:									
Yellowfin	1.2	4.4	11.1	13.3	36.8	48.1	1.1	5.3	9.5
Bigeye	3.0	2.2	5.5	25.0	34.9	30.5	6.6	1.9	3.6
Fish (total):									
Yellowfin	79.2	52.1	71.1	96.7	94.5	90.9	69.8	62.5	60.3
Bigeye	28.0	94.0	81.5	62.5	85.7	85.3	62.0	80.9	53.0
Bramidae:									
Yellowfin	14.7	9.5	12.4	43.3	61.7	62.0	13.0	11.4	10.5
Bigeye	1.5	15.0	30.7	25.0	25.4	38.9	3.4	12.9	20.0
Gempylidae:									
Yellowfin	4.8	5.8	8.0	36.7	31.8	31.2	4.2	6.9	6.8
Bigeye	21.9	18.5	12.2	12.5	38.1	38.9	48.5	15.9	7.9
Thunnidae:									
Yellowfin	1.6	5.9	25.5	10.0	5.0	11.1	1.4	7.0	21.7
Bigeye	0.0	10.8	2.4	0.0	3.2	3.2	0.0	9.3	1.5
Sudidae:									
Yellowfin	0.7	0.6	0.3	10.0	10.4	2.9	0.6	0.7	0.3
Bigeye	3.7	5.1	3.1	12.5	17.5	16.8	8.2	4.4	2.0
Molidae:									
Yellowfin	38.2	9.6	6.0	6.7	3.0	1.9	33.7	11.5	5.1
Bigeye	0.0	4.2	0.0	0.0	4.8	0.0	0.0	3.6	0.0
Other foods:									
Yellowfin	1.1	0.8	0.3	26.7	32.8	15.4	1.0	1.0	0.3
Bigeye	0.7	0.2	0.1	12.5	6.3	6.3	1.5	0.1	0.0
All foods									
Yellowfin	113.4	83.9	117.9						
Bigeye	45.1	116.2	153.8						
Number of stomachs:									
Yellowfin	30	201	208						
Bigeye	8	63	95						
Average fork length (cm.):									
Yellowfin	138	140	142						
Bigeye	153	139	148						
Average weight (lbs.):									
Yellowfin	112	118	123						
Bigeye	166	125	149						
Average volume (cc.) food per pound of body weight:									
Yellowfin	1.0	0.7	1.0						
Bigeye	0.3	0.9	1.0						

TABLE 5.—*Variation in volume and composition of stomach contents with time of year at which the tunas were captured*

Food organisms	Average volume (cc.) per stomach				Percentage by occurrence				Percentage of total volume			
	Jan.–March	April–July	Aug.–Sept.	Oct.–Nov.	Jan.–March	April–July	Aug.–Sept.	Oct.–Nov.	Jan.–March	April–July	Aug.–Sept.	Oct.–Nov.
Crustaceans:												
Yellowfin	1.1	0.2	0.6	2.1	60.1	26.8	29.9	43.6	1.2	0.1	0.7	2.4
Bigeye	1.9	1.4	1.1	5.3	48.0	37.0	25.9	48.8	1.4	0.7	1.1	4.6
Squids:												
Yellowfin	27.0	34.4	40.3	21.1	94.5	76.0	96.3	91.0	28.8	22.2	41.2	25.1
Bigeye	21.8	72.4	40.3	30.9	80.0	78.3	85.1	92.7	16.0	37.3	40.9	26.8
Other mollusks:												
Yellowfin	7.9	14.5	4.5	5.4	46.9	47.9	39.3	21.0	8.4	9.3	4.7	6.4
Bigeye	3.2	3.9	5.6	2.9	48.0	30.4	13.0	26.8	2.3	2.0	5.6	2.5
Fish (total):												
Yellowfin	56.9	105.7	52.0	54.8	96.1	91.5	90.7	97.0	60.6	68.1	53.2	65.1
Bigeye	109.5	116.4	51.4	76.2	92.0	89.1	70.3	95.2	80.2	60.0	52.1	66.0
Bramidae:												
Yellowfin	8.0	14.9	14.1	10.8	60.1	50.7	69.2	60.9	8.5	9.6	14.4	12.9
Bigeye	29.1	51.8	4.5	12.8	24.0	43.5	33.3	31.7	21.3	26.7	4.6	11.1
Gempylidae:												
Yellowfin	8.1	8.0	1.9	8.6	45.3	23.9	24.3	28.6	8.7	5.2	2.0	10.2
Bigeye	11.5	16.9	8.0	24.3	48.0	37.0	28.0	39.0	8.4	8.7	8.1	21.4
Thunnidae:												
Yellowfin	10.4	25.7	25.1	5.2	7.8	16.9	5.6	5.3	11.1	16.6	25.7	6.2
Bigeye		4.9		16.6		6.5		4.9		2.5		14.4
Subidae:												
Yellowfin	0.9	0.2	0.0	0.5	13.3	7.0	0.9	5.3	1.0	0.1	0.0	0.6
Bigeye	13.0	2.6	2.2	1.8	36.0	19.6	5.6	12.2	9.5	1.3	2.2	1.5
Molidae:												
Yellowfin	0.0	32.9	0.2	14.7	0.0	12.6	0.9	2.3	0.0	21.2	0.2	17.5
Bigeye		3.0		3.0		2.2		4.9		1.6		2.6
Other foods:												
Yellowfin	0.9	0.3	0.3	0.8	43.7	9.9	7.5	25.6	0.9	0.2	0.3	0.9
Bigeye	0.2	0.03	0.2	0.1	12.0	6.5	3.7	9.8	0.2	0.02	0.2	0.08
All foods:												
Yellowfin	93.8	155.2	97.7	84.1								
Bigeye	136.6	194.1	98.7	115.3								
Number of stomach examined:												
Yellowfin	128	71	107	123								
Bigeye	25	46	54	41								
Average fork length (cm.):												
Yellowfin	140	141	140	141								
Bigeye	148	141	149	146								
Average weight (lbs.):												
Yellowfin	119	121	116	120								
Bigeye	148	129	151	142								
Average volume (cc.) food per pound of body weight:												
Yellowfin	0.8	1.3	0.8	0.7								
Bigeye	0.9	1.5	0.7	0.8								

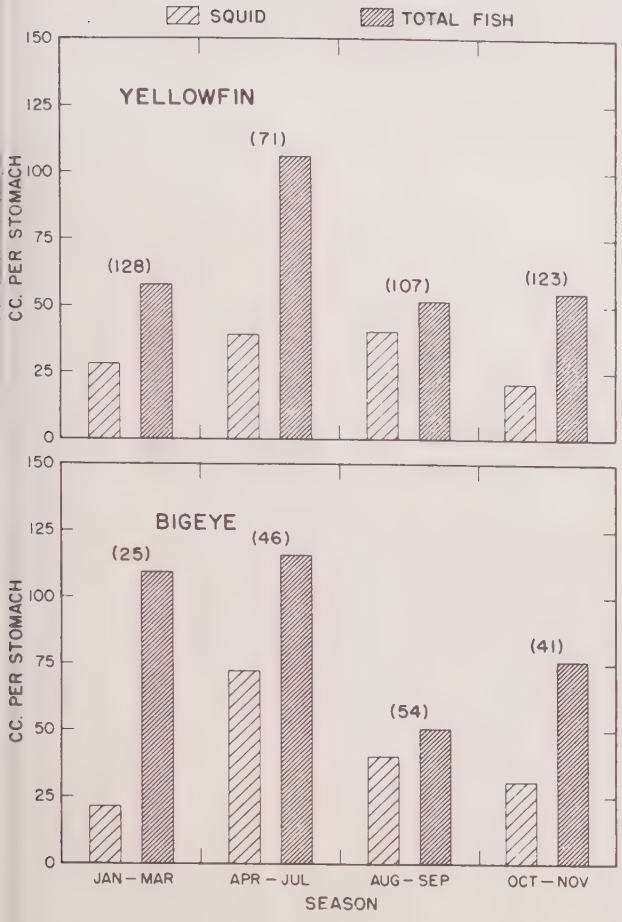


FIGURE 10.—Variation in the major foods as related to the general longitude of capture of the tunas. Number of stomachs is shown in parentheses.

of the major food items shown in figure 10. The chief similarity between the two species lies in the lower volume of total fish in the food of tunas captured in the region of 140°–150° W. longitude. The utilization of squid, Bramidae, Gempylidae, and Thunnidae does not vary in any regular pattern for the two species. A majority of the Thunnidae appearing in the food of yellowfin captured in the area of 120°–130° W. were *Auxis thazard*, which was not prominent in the food in the more western regions and which in the bigeye was represented by only one specimen, also from the 120°–130° W. region.

For both bigeye and yellowfin, the largest specimens were captured in the eastern region (120–130° W.) and the smallest in the western region (155° W–180°). When the variation in volume of stomach contents is considered in terms of unit volume per unit of body weight, we find only slight regional differences for the yellowfin but a rather large variation for the bigeye (table 6). In the bigeye, specimens from the western region contained 1.5 cc. of food per pound of body weight, as compared with 0.6 cc. for specimens from the central region and 1.0 cc. for specimens from the eastern region. These three values closely parallel the corresponding average volumes of total fish per stomach (115.3, 55.4, and 95.8 cc.).

Variation with the Current System

The general pattern of the Pacific equatorial-current system has been described by Sverdrup and associates (1942, pp. 708–712). In brief, the major surface currents of this region are the North and South Equatorial Currents flowing toward the west, with the eastward-flowing Equatorial Countercurrent sandwiched in between. Although the width of the Countercurrent (CC) may vary with longitude and season, its southern and northern boundaries are ordinarily near latitudes 5° N. and 10° N. in the Central Pacific. The South Equatorial Current (SEC) is therefore on both sides of the Equator, while the North Equatorial Current (NEC) is confined entirely to the Northern Hemisphere.

The prevailing east to southeast tradewinds, together with the Coriolis force resulting from the earth's rotation, induce a divergence of the surface waters at the Equator that is accompanied by upwelling. Under certain conditions, described by Cromwell (1953) a convergence may be formed, between the Equator and the southern boundary of the CC, which, we hypothesize, may tend to concentrate plankton and, consequently, the tuna forage organisms.

Over the range of latitude sampled (17° N.–14° S.), there are therefore certain natural subdivisions of the environment that may be established on the basis of the features mentioned above. These may be defined as follows: (1) The NEC from the northern limit of our sampling (17° N.) to the northern boundary of the CC; (2) the CC, with its boundaries determined at the time of each crossing from vertical temperature sections;[6] (3) a zone of convergence in the SEC extending—according to our definition—from the southern boundary of the CC to latitude 1½° N.; (4) a zone of divergence or upwelling in the SEC along the Equator from latitude 1½° N. to latitude 1½° S.; and (5)

[6] Provided in the reports of Murphy and Shomura (1953a, 1953b, 1955).

TABLE 6.—*Variation in volume and composition of stomach contents with longitude of place of capture*

Food organisms	Average volume (cc.) per stomach			Percentage by occurrence			Percentage of total volume		
	180°–155° W	150°–140° W	130°–120° W	180°–155° W	150°–140° W	130°–120° W	180°–155° W	150°–140° W	130°–120° W
Crustaceans:									
Yellowfin	1.8	0.8	0.4	48.3	42.6	29.8	1.9	0.9	0.3
Bigeye	2.1	1.4	5.0	49.1	30.7	35.3	1.2	1.4	3.1
Squids:									
Yellowfin	21.6	37.7	28.8	90.7	96.7	78.5	23.3	40.0	21.1
Bigeye	50.1	35.5	52.9	82.4	84.0	88.2	29.4	36.5	33.4
Other mollusks:									
Yellowfin	4.6	5.3	17.5	26.2	46.4	40.5	5.0	5.7	12.8
Bigeye	2.7	4.9	4.5	33.3	24.0	20.6	1.6	5.1	2.8
Fish (total):									
Yellowfin	64.0	49.8	89.7	97.1	92.9	91.6	68.8	52.9	65.7
Bigeye	115.3	55.4	95.8	91.2	76.0	94.1	67.7	56.9	60.5
Bramidae:									
Yellowfin	10.5	12.1	11.9	56.4	72.7	45.2	11.4	12.9	8.7
Bigeye	48.3	6.0	19.8	36.8	30.7	38.2	28.3	6.2	12.5
Gempylidae:									
Yellowfin	6.3	3.8	14.3	27.3	38.2	26.2	6.7	4.0	10.5
Bigeye	16.5	9.4	24.8	31.6	34.7	47.0	9.7	9.6	15.7
Thunnidae:									
Yellowfin	7.3	15.4	29.4	7.0	4.4	17.8	7.8	16.4	21.5
Bigeye	12.3		5.9	7.0		2.9	7.2		3.8
Sudidae:									
Yellowfin	0.7	0.2	0.6	9.3	6.6	2.4	0.7	0.2	0.4
Bigeye	3.8	5.1	1.1	24.6	12.0	8.8	2.2	5.2	0.7
Molidae:									
Yellowfin	19.1	0.1	11.9	6.4	0.5	1.2	20.6	0.1	8.7
Bigeye	4.6			5.3			2.7		
Other foods:									
Yellowfin	0.9	0.5	0.2	29.7	22.4	15.5	1.0	0.5	0.2
Bigeye	0.09	0.2	0.1	7.0	5.3	11.8	0.05	0.2	0.08
All foods:									
Yellowfin	92.9	94.1	136.6						
Bigeye	170.3	97.4	158.4						
Number of stomachs examined:									
Yellowfin	172	183	84						
Bigeye	57	75	34						
Average fork length (cm.):									
Yellowfin	136	141	147						
Bigeye	136	150	152						
Average weight (lbs.):									
Yellowfin	108	121	138						
Bigeye	116	155	160						
Average volume (cc.) food per pound of body weight:									
Yellowfin	0.9	0.8	1.0						
Bigeye	1.5	0.6	1.0						

the SEC from 1½° S. to the southern limit of our sampling (14° S.).

These areas have the following characteristics affecting the abundance of fish food: Area 1 is a region of low zooplankton concentrations (King and Demond 1953) and shallow thermocline. In area 2 the thermocline deepens to the south, and zooplankton shows some increase in abundance. Area 3 has a deep thermocline and a relatively high concentration of zooplankton. In area 4 at the Equator, upwelling is evidenced by a doming of the isotherms, a reduction in surface temperature, an increase in surface inorganic phosphate, and frequently by the greatest concentration of zooplankton. In area 5 the thermocline deepens, and the zooplankton concentration is reduced.

When the yellowfin and bigeye catch records [7] during the years 1950–53 are combined according to these natural features of the environment, we observe (fig. 11, A) that the area of best catch for yellowfin was in the convergence zone (area 3), while the best catches of bigeye came from the NEC (area 1) and the CC (area 2). Thus the longline catch provides some indication of an inverse relation in the abundance of these two species.

The stomach-content volumes were combined in the same manner—disregarding the rather minor differences associated with depth of capture, longitude, and season—to produce parts B and C of figure 11.[8] For the yellowfin, we find no correspondence between catch per 100 hooks and

[7] Summarized in reports of Murphy and Shomura (1953a, 1953b, 1955).

[8] Parts B and C of figure 11 are based on the 439 yellowfin stomachs employed in this report, which were considered comparable with the bigeye collections, and not on our total yellowfin-stomach data from the central Pacific.

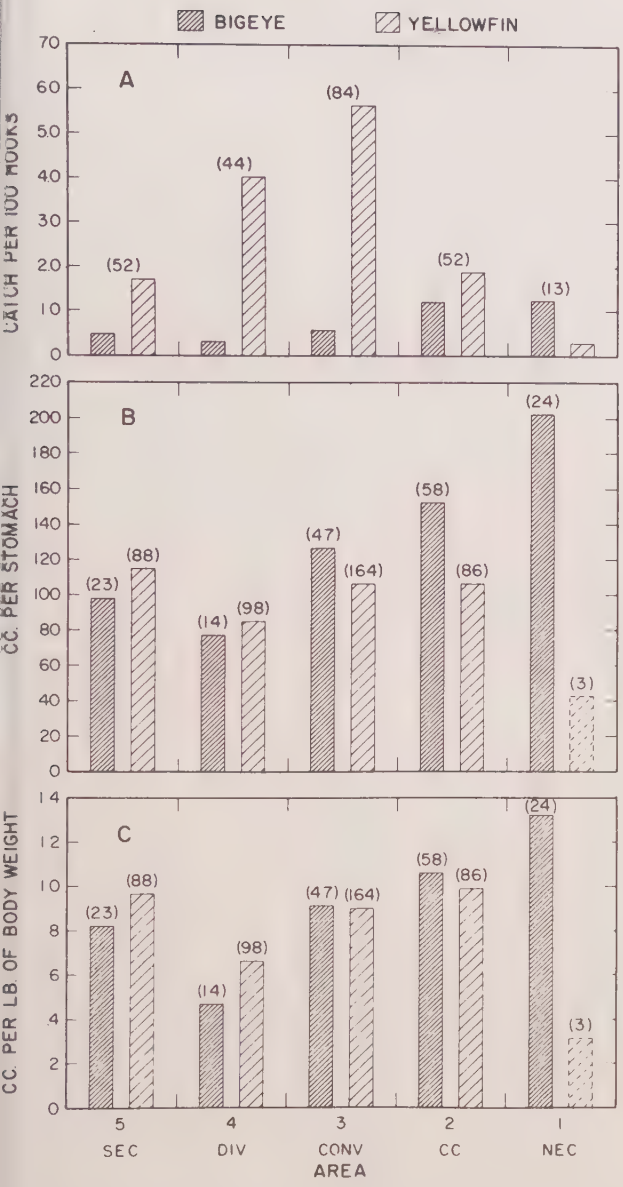


FIGURE 11.—Variations with the current system in (A) yellowfin and bigeye catch on longline gear, (B) average volume of food per stomach, and (C) average volume of food per pound of body weight. Boundaries for each division of the current system are defined in the text. Part A is derived from cruises 7, 11, and 18 of the *Hugh M. Smith*, cruises 11, 12, 13, 14, and 15 of the *John R. Manning*, cruise 1 of the *Charles H. Gilbert*, and cruise 1 of the *Cavalieri*. Number of observations, as stations fished (part A) or stomachs examined (parts B and C), is shown in parentheses.

volume of stomach contents.[9] The divergence zone at the Equator produced good catches of yellowfin, but these fish contained the lowest food volumes. On the basis of both the average volume of food per stomach and the average volume of food per pound of body weight—disregarding the three stomachs collected from the NEC—we judge that the yellowfin captured in areas 2, 3, and 5 were equally well fed. In the bigeye, there is a suggestion of parallel variation in catch rate and volume of stomach contents. This species was the best fed in areas 1 and 2, which were also the areas of best catch. The bigeye from near the Equator (area 4), where catches were poorest, contained the lowest food volumes.

Table 7 illustrates variations in certain food components as related to the system of currents. The consumption of Crustacea by yellowfin is roughly in accordance with the varying abundance of zooplankton as determined from our plankton surveys (King and Demond 1953, King 1954). Their utilization by bigeye is quite different, however, and may be related to differences in the kinds of organisms involved. In the food of yellowfin, for example, the crustacean fraction was principally amphipods, with isopods and crab larvae of some importance; the bigeye had fed chiefly on shrimp and euphausids. The complex variations in the consumption of squid, Bramidae (chiefly *Collybus drachme*), Gempylidae (chiefly *Gempylus serpens*), and total fish are difficult to understand, since we lack information on the latitudinal variations in abundance of these forage organisms.

We should like next to examine in greater detail the differences between the CC (area 2) and the convergent zone (area 3) with respect to volume and composition of food utilized as related to depth of capture of the tunas. As previously stated, the CC is a region of relatively good catch for bigeye and of poor catch for yellowfin. Bigeye from this region contained about 50 percent more food in their stomachs than did the yellowfin, but they averaged somewhat larger in body size.

[9] It was previously reported (Reintjes and King 1953) that on one cruise (cruise 11, *Hugh M. Smith*) there was some indication that for yellowfin the average volume of stomach contents varied directly with the catch rate.

TABLE 7.—*Variations in average volume per stomach of the major food categories as related to the current system*

[Boundaries of each area or division of current system are defined in text; volume is measured in cc.]

Food organisms	Area 1, NEC	Area 2, CC	Area 3, Conv.	Area 4, Div.	Area 5, SEC
Crustaceans:					
Yellowfin		0.3	0.6	2.9	0.8
Bigeye	0.1	2.1	3.3	1.8	3.8
Squids:					
Yellowfin	34.3	38.0	30.7	33.1	16.6
Bigeye	38.9	73.1	32.3	29.2	11.9
Other mollusks:					
Yellowfin		2.7	12.5	4.1	6.1
Bigeye	7.1	1.3	8.1	0.7	1.4
Fish (total):					
Yellowfin	8.0	64.9	62.2	44.0	91.6
Bigeye	155.7	75.4	82.6	45.5	80.6
Bramidae:					
Yellowfin	0.7	8.5	16.4	6.6	9.1
Bigeye	5.0	41.0	22.5	0.5	5.4
Gempylidae:					
Yellowfin	4.0	8.1	4.2	5.0	12.8
Bigeye	37.2	6.9	18.1	11.7	16.5
Thunnidae:					
Yellowfin		20.2	18.3	16.6	1.5
Bigeye	28.3	3.5			
Sudidae:					
Yellowfin			0.2	0.1	1.3
Bigeye	0.6	1.6	5.7	1.1	10.9
Molidae:					
Yellowfin		2.5	1.2		44.6
Bigeye	5.2				6.1
Other foods:					
Yellowfin		0.2	5.7	0.7	0.9
Bigeye			0.2	0.1	0.3
All foods:					
Yellowfin	42.3	106.6	106.6	84.8	115.3
Bigeye	201.9	152.0	126.4	77.3	97.9
Number of stomachs examined:					
Yellowfin	3	86	164	98	88
Bigeye	24	58	47	14	23
Average fork length (cm.):					
Yellowfin	147	136	141	144	140
Bigeye	149	146	145	153	138
Average weight (lbs.):					
Yellowfin	138	108	119	129	118
Bigeye	153	143	139	164	120
Average volume (cc) food per pound of body weight:					
Yellowfin	0.3	1.0	0.9	0.7	1.0
Bigeye	1.3	1.1	0.9	0.5	0.8

On the basis of average volume of food per pound of body weight there was little difference between the two species.

The region of convergence has yielded the best yellowfin catches but has produced consistently poor bigeye catches. In this region the bigeye had about 20 percent more food in their stomachs than did the yellowfin, but the bigeye were also larger in average body size. Again the two species were almost identical with respect to average volume of food per pound of body weight.

In the CC, the thermocline occurs at shallow to moderate depths, while in the convergent zone it lies much deeper. Accompanying changes in the depth and velocity of the surface currents may greatly affect the fishing depth of the longline. In the region of shallow thermocline it is possible that, as a result of the streaming of the line caused by the marked shear between the moving surface waters and the relatively quiet waters below the thermocline, all hooks may be fishing at about the same level (Murphy and Shomura 1953b), and no marked difference might be expected in the food between the various hook levels. In a region of deep thermocline the longline can hang vertically and lie entirely within the homogenous surface layer. A marked difference in hook depth and possible differences in the stomach contents of the catch may then result.

Data have been assembled in table 8 and figure 12 to illustrate the variations in average volume per stomach for the major food categories with depth of capture of the tunas in these two ocean areas. In the CC there is greater change in the food of yellowfin with depth than in the convergent zone; this is evidenced by a consistent increase with depth, in the CC, in the utilization of Bramidae, Gempylidae, and total fish. In the bigeye the only important and consistent variation shown in the CC is a marked increase with depth in the amount of Crustacea eaten and a decrease in the importance of Gempylidae, as contrasted with

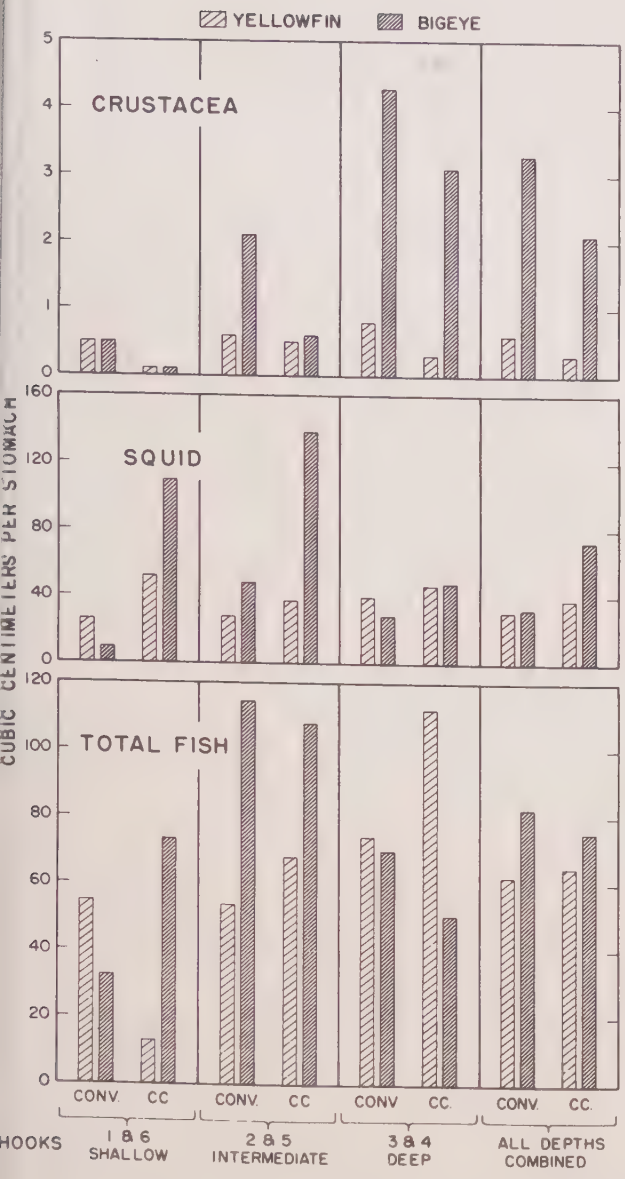


FIGURE 12.—Variations in average volume per stomach of the major food categories with depth of capture of 250 yellowfin and 105 bigeye tuna taken by longline in the Countercurrent and the convergent zone.

the increase with depth in Gempylidae as noted for yellowfin. In the convergent zone there is a similar increase with depth in the utilization of Crustacea and Bramidae.

The major foods are of about equal importance in both areas. There is no indication that the tunas have one set of foods in the CC and another in the convergent zone. The main difference between the two species is the much greater consumption of Crustacea by the bigeye in both the CC and the convergent zone. If we may consider the longline catch rate as an index to abundance, it would appear that the bigeye responds in a different manner than the yellowfin to the more favorable foraging conditions which, we hypothesize, exist in the convergent zone.

OTHER VARIATIONS IN VOLUME OF STOMACH CONTENTS

When the stomach-content volumes are classified according to an arbitrary scale, the results (table 9) indicate for both species a rather low percentage of empty or near-empty stomachs; the average stomach contained a relatively small amount of food. This may mean that feeding is almost continuous, as contrasted with an irregular or spasmodic feeding habit, and that these fish have a high rate of digestion. For instance, it is hard to believe that a food volume of less than 100 cc., which was found in more than 50 percent of the stomachs (table 9), constitutes a daily or even semidaily ration for these large active fish. Unfortunately, our food studies provide no information on rate of food consumption or digestion.

In longline fishing, the gear is ordinarily set at daybreak and is hauled in during the afternoon. The time of landing is known, but not the time that the fish took the hook. On some cruises, 50 percent or more of the tuna are dead when landed. One might assume that these fish had been on the line for a longer period of time than the fish that were landed alive. On the basis of this hypothesis we examined the records from certain cruises for which we had the greatest number of observations supplying information on condition when landed. These data, as summarized in table 10, seem to indicate that the fish that were dead when landed contained larger volumes of food, on the average, than those that were landed alive. Although we cannot satisfactorily explain this difference, we believe that it may be related to the tendency for more dead fish to occur on the deep hooks than on the hooks fishing at shallow and intermediate depths; and in the yellowfin, at least, we have found an increase in volume of stomach contents with depth of capture (table 3). A combination of these factors might produce the results shown in table 10.

TABLE 8.—*Variations in average volume of food per stomach in pelation to depth of capture, comparing yellowfin and bigeye tuna taken by longline in the Countercurrent and convergent zone*

[Organisms making up less than 1 percent of the total food volume for each depth category were omitted from table; volume is measured in cc.]

Food organisms	Convergent zone						Countercurrent					
	Yellowfin			Bigeye			Yellowfin			Bigeye		
	Hooks 1 and 6 (shallow)	Hooks 2 and 5 (intermediate)	Hooks 3 and 4 (deep)	Hooks 1 and 6 (shallow)	Hooks 2 and 5 (intermediate)	Hooks 3 and 4 (deep)	Hooks 1 and 6 (shallow)	Hooks 2 and 5 (intermediate)	Hooks 3 and 4 (deep)	Hooks 1 and 6 (shallow)	Hooks 2 and 5 (intermediate)	Hooks 3 and 4 (deep)
Crustacea (total)	0.5	0.6	0.8	0.5	2.1	4.3	0.1	0.5	0.3	0.1	0.6	3.1
Penaeidae						4.2						2.6
Squids (total)	25.5	27.6	39.4	9.2	47.7	28.4	52.1	37.4	46.5	110.0	138.5	47.8
Loliginidae:												
Loligo sp.						1.7						
Sepioteuthis sp.			1.8			2.9	12.3		2.8	43.0	4.9	14.6
Unidentified Loliginidae	3.1		4.6		20.1	3.7		8.2	18.0	39.6	11.0	2.5
Onycoteuthidae					5.2							1.3
Enoploteuthidae:												
Abralia sp.						1.2						
Unidentified Enoploteuthidae						3.3	2.1	1.8	1.9	7.1		5.5
Ommastrephidae:												
Ommastrephes sp.									3.4			
Notodarus sp.												5.5
Unidentified Ommastrephidae	7.3	4.6	2.1	5.1	5.0	8.8	5.0	7.3	3.6	8.1	103.1	4.5
Sepiolidae		2.0						2.9	3.4		17.6	
Cranchiidae:												
Liocranchia globulus								1.4	2.9			12.0
Unidentified Cranchiidae												
Other mullusks (total)	14.3	8.4	15.4		0.9	12.3	1.4	3.3	2.6		1.5	1.1
Octopodidae	2.0	2.3	10.6			7.5		1.5				
Argonautidae:												
Argonauta sp.			2.1			1.9						
A. hottgeri	1.6	1.0				2.5						
Unidentified Argonautidae	10.3	3.5	1.2				0.9	1.6				1.1
Fish (total)	54.7	53.8	74.2	32.5	114.6	70.0	12.9	68.0	111.9	73.3	107.9	50.7
Gonostomidae: *Vinciguerria lucetia*						1.2						
Sternoptychidae:												
Sternoptyx diaphana	9.7					2.7						
Unidentified Sternoptychidae				0.6		0.6				3.6		1.1
Sudidae:												
Paralepis sp.					9.0	1.8						
Unidentified Sudidae				26.3		0.5						4.2
Alepisauridae: *Alepisaurus* sp.												2.1
Exocoetidae:												
Cyselurus sp.		1.7										
Unidentified Exocoetidae		0.1						3.4				
Trachypteridae: *Trachypterus* sp.						1.4						
Caulolepidae									3.6			
Atherinidae: *Atherinus insularum*						2.0						
Priacanthidae: *Priacanthus cruentatus*							1.2					
Carangidae:												
Seriola sp.	1.8											
Naucrates sp.	2.4											
Scombroides sp.		2.4										
Bramidae:												
Collybus drachme	10.1	15.3	8.5	3.5		9.9		4.0	12.4		61.7	17.9
Taractes sp.	1.4	1.1	4.6		8.2	14.9			4.1		4.5	
Unidentified Bramidae	2.6	1.0	0.4		1.3	7.7	4.6	3.5	0.6		1.4	2.4
Chiasmodontidae												1.3
Gempylidae:												
Gempylus serpens	2.0	1.3	5.2		39.0	4.2	1.2	4.3	15.5	9.5	9.5	2.3
Unidentified Gempylidae	1.2	1.7	1.3	0.6		0.4		1.0	3.2	9.5	0.4	2.9
Nomeidae:												
Nomeus sp.						2.3						
Unidentified Nomeidae						0.1	0.8					
Thunnidae:												
Katsuwonus pelamis	8.1	4.4	12.8					28.2	41.1			
Neothunnus macropterus			15.8									
Auxis thazard		6.4	4.2									9.2
Unidentified Thunnidae			1.1					0.3				1.0
Echeneidae:												
Echeneis sp.	1.4											
Remora remora							0.9	3.8				
Unidentified Echeneidae	0.2						0.3	0.8				
Balistidae:												
Balistes nycteris	1.2	4.3										
Unidentified Balistidae	0.2	0.8										
Ostraciidae:												
Ostracion diaphanus			1.9									
Lactoria schlemmeri						2.3						
Unidentified Ostraciidae			3.3				0.7					
Tetrodontidae: *Tetrodon* sp.		1.3										
Molidae: *Ranzania* sp.	4.0							6.8	1.7			
Other foods	0.5	0.4	0.8		0.7				0.6			0.1
All foods	95.6	90.8	130.4	42.2	166.0	115.3	66.5	109.5	161.9	183.4	248.6	103.9
Number of stomachs examined	49	49	61	3	14	28	9	25	25	7	13	22
Average fork length (cm.)	141	141	141	146	153	141	131	135	139	153	146	140
Average weight (lbs.)	120	120	120	139	164	130	97	106	115	162	144	127
Average volume of food per pound of body weight (cc.)	0.8	0.8	1.1	0.3	1.0	0.9	0.7	1.0	1.4	1.1	1.7	0.8

TABLE 9.—*Distribution of the volume of stomach contents of 439 yellowfin and 166 bigeye caught by longline fishing in the central Pacific*

Volume (cc.)	Less than 140 cm. long			140 cm. or larger		
	Number	Percent of total number	Accumulated percentage	Number	Percent of total number	Accumulated percentage
Empty:						
(0–0.9):						
Yellowfin	6	3.2	3.2	4	1.6	1.6
Bigeye	2	3.2	3.2	6	5.8	5.8
1.0–9.9:						
Yellowfin	17	9.0	12.2	17	6.7	8.3
Bigeye	4	6.3	9.5	10	9.7	15.5
10.0–24.9:						
Yellowfin	21	11.2	23.4	22	8.7	17.0
Bigeye	9	14.3	23.8	9	9.4	24.9
25.0–49.9:						
Yellowfin	45	24.0	47.4	50	19.9	36.9
Bigeye	10	15.8	39.6	13	12.6	37.5
50.0–99.9:						
Yellowfin	49	26.1	73.5	66	26.2	63.1
Bigeye	11	17.5	57.1	18	17.5	55.0
100.0–199.9:						
Yellowfin	31	16.5	90.0	56	22.2	85.3
Bigeye	13	20.6	77.7	24	23.3	78.3
200.0–499.9:						
Yellowfin	15	8.0	98.0	30	11.9	97.2
Bigeye	12	19.0	96.7	17	16.5	94.8
500.0–999.9:						
Yellowfin	4	2.1	100.0	3	1.2	98.4
Bigeye	2	3.2	100.0	5	4.9	99.7
1000.0 and over:						
Yellowfin	0	0.0		3	1.2	100.0
Bigeye	0	0.0		1	1.0	100.0
Total:						
Yellowfin	188			251		
Bigeye	63			103		

TABLE 10.—*Summary of data relating average volume of stomach contents to condition of fish, whether dead or alive, at time of landing*

Cruise	Yellowfin			Bigeye		
	Average volume of stomach contents	Number of stomachs examined	Average fork length	Average volume of stomach contents	Number of stomachs examined	Average fork length
	cc.		*cm.*	*cc.*		*cm.*
Hugh M. Smith cruise 11:						
Landed dead	93.7	64	135	174.9	11	152
Landed alive	50.6	23	141	83.5	24	148
John R. Manning cruise 14:						
Landed dead	95.6	37	143			
Landed alive	71.4	32	144			
John R. Manning cruise 15:						
Landed dead				100.9	9	119
Landed alive				280.5	10	137

SUMMARY AND CONCLUSIONS

1. This study is based on the quantitative analysis of the stomach contents of 166 bigeye tuna (*Parathunnus sibi*) and of 439 yellowfin tuna (*Neothunnus macropterus*) caught at the same time or nearly the same time as the bigeye.

2. These tuna were captured in the central Pacific during the period October 1950–June 1953 by means of longline-gear fishing at depths of 150 to 500 feet.

3. The food of the yellowfin consisted of fish (62 percent by volume), squid (29 percent), other mollusks (7 percent), and crustaceans (1 percent); the food of bigeye consisted of fish (62 percent), squid (33 percent), other mollusks (3 percent), and crustaceans (2 percent).

4. Both species of tuna appear to utilize a great variety of animal food, ranging from small plankton organisms to large squid and fish. Food items of major importance to both species were pomfret (*Collybus drachme*), snake mackerel (*Gempylus serpens*), and squid of the families Ommastrephidae and Loliginidae.

5. This great diversity of diet suggests that many forms of fish, squid, and shrimp—if available through culture or capture—might be effective as live bait or longline bait in tuna fishing.

6. Stomatopod crustaceans, common in the food of yellowfin, were completely lacking from the bigeye stomachs. The young of other tunas, mostly skipjack, formed a much more important part of the yellowfin diet than of the bigeye diet.

7. In both species, the larger tuna had more food in their stomachs than did the smaller fish, but the larger fish contained less food per pound of body weight than did the smaller fish. There were few completely empty stomachs.

8. In both tunas, the smaller individuals consumed a greater proportion by volume of crustaceans and fish and a lesser proportion of mollusks than the larger size group. The same fish families were prominent in the diet of both size groups.

9. There was an increase in volume of stomach contents with depth of capture for the yellowfin; in the bigeye, the largest volumes were found in specimens from intermediate depths. There was no marked variation in composition of stomach contents over the range of depth sampled (estimated at 150 to 500 feet), which may be evidence that both the forage organisms and the tuna range rather freely throughout this water layer.

10. In both yellowfin and bigeye, fish were consumed in greatest amount during the period April–July, and in least amount during August and September. There was little correspondence between the two species in the seasonal variation in the other major food items.

11. In respect to longitudinal variations in the food, the two species were similar in the lower volume of total fish in the stomach contents of those tunas captured in the central region (140°–150° W. longitude) of the sampled area. The utilization of specific foods did not vary with longitude in any regular pattern for the two species.

12. When classified according to natural subdivisions of the equatorial current system, the volume of stomach contents in the bigeye varied directly with the longline catch rate, while in the yellowfin there was little change in volume of stomach contents with even a marked change in catch rate.

13. Tuna that were dead when landed contained, on the average, more food in their stomachs than those landed alive.

14. Despite the differences that we have pointed out, the foods of the yellowfin and bigeye are remarkably similar. We conclude, therefore, that when occupying the same general area the two species have essentially the same feeding habits. If there is any marked food selection, it must be exercised by seeking different areas for feeding.

LITERATURE CITED

Berg, L. S.
1947. Classification of fishes both recent and fossil. J. W. Edwards, Ann Arbor, Mich. 517 pp.

Brock, V. E.
1949. A preliminary report on *Parathunnus sibi* in Hawaiian waters and a key to the tunas and tuna-like fishes of Hawaii. Pacific Science, vol. 3, No. 3, pp. 271–277.

Cromwell, Townsend
1951. Mid-Pacific oceanography, January through March 1950. U. S. Fish and Wildlife Service, Spec. Sci. Rept.—Fisheries No. 54. 77 pp.
1953. Circulation in a meridional plane in the central equatorial Pacific. Journal of Marine Research, vol. 12, No. 2, pp. 196–213.

Kanagawa Prefecture Fisheries Experiment Station
1951. Report of South Seas tuna fishery investigations. 162 pp. (Partial translation from the Japanese by W. G. Van Campen in the files of Pacific Oceanic Fishery Investigations.)

King, J. E.
1954. Variations in zooplankton abundance in the central equatorial Pacific, 1950–52. Fifth Meeting, Indo-Pacific Fisheries Council, Symposium on marine and fresh-water plankton in the Indo-Pacific, pp. 10–17.

King, J. E., and Joan Demond
1953. Zooplankton abundance in the central Pacific. U. S. Fish and Wildlife Service, Fishery Bull. 54, vol. 82, pp. 111–144.

Murphy, G. I., and R. S. Shomura
1953a. Longline fishing for deep-swimming tunas in the central Pacific, 1950–51. U. S. Fish and Wildlife Service, Spec. Sci. Rept.—Fisheries No. 98. 47 pp.
1953b. Longline fishing for deep-swimming tunas in the central Pacific, January–June. 1952. U. S. Fish and Wildlife Service, Spec. Sci. Rept.—Fisheries No. 108, 32 pp.
1955. Longline fishing for deep-swimming tunas in the central Pacific, August-November 1952. U. S. Fish and Wildlife Service, Spec. Sci. Rept.—Fisheries No. 137. 42 pp.

Nakamura, Hiroshi
1949. The tunas and their fisheries. Tokyo: Takeuchi Shobō. Translated from the Japanese by W. G. Van Campen, U. S. Fish and Wildlife Service, Spec. Sci. Rept.—Fisheries No. 82, 1952. 115 pp.

Niska, E. L.
1953. Construction details of tuna longline gear used by Pacific Oceanic Fishery Investigations. U. S. Fish and Wildlife Service, Commercial Fisheries Review, vol. 15, No. 6, pp. 1–6.

ITSU, TAMIO
1954. Analysis of the Hawaiian longline fishery, 1948–52. U. S. Fish and Wildlife Service, Commercial Fisheries Review, vol. 16, No. 9, pp. 1–17.

EINTJES, J. W., and J. E. KING
1953. Food of yellowfin tuna in the central Pacific. U. S. Fish and Wildlife Service, Fishery Bull. 54, vol. 81, pp. 91–110.

ETTE, O. E.
1955. Consideration of mid-ocean fish production as related to oceanic circulatory systems. Journal of Marine Research, vol. 14, No. 4, pp. 398–414.

SETTE, O. E., and STAFF OF PACIFIC OCEANIC FISHERY INVESTIGATIONS
1954. Progress in Pacific Oceanic Fishery Investigations, 1950–53. U. S. Fish and Wildlife Service, Spec. Sci. Rept.—Fisheries No. 116. 75 pp.

SUYEHIRO, YASUO
1942. A study of the digestive system and feeding habits of fish. Japanese Journ. Zool., vol. 10, No. 1, pp. 1–303.

SVERDRUP, H. U., M. W. JOHNSON, and R. H. FLEMING
1942. The oceans, their physics, chemistry, and general biology. Prentice-Hall, Inc., New York, N. Y. 1087 pp.

APPENDIX

TABLE 11.—*Check-list of food organisms found in the stomachs of 439 yellowfin and 166 bigeye tuna captured on longline in the Central Pacific, 1950–53*

[Family names of fishes are as given in Berg 1947]

Food organisms	Yellowfin					Bigeye				
	Number of organisms	Stomachs in which occurred		Aggregate total volume		Number of organisms	Stomachs in which occurred		Aggregate total volume	
		Number	Percent	Cubic centimeters	Percent [1]		Number	Percent	Cubic centimeters	Percent [1]
CTENOPHORA						1	1	0.6	0.1	
ARTHROPODA										
Crustacea	[1,761]	[188]	[42.8]	[496.1]	[1.1]	[669]	[67]	[40.4]	[398.0]	[1.7]
Mysidacea:										
Mysidae:										
Mysis sp.	8	1	0.2	6.3						
Unidentified mysids	52	2	0.5	4.9						
Isopoda:										
Idotheidae	175	44	10.0	34.4		103	12	7.2	3.7	
Cymotheidae	27	2	0.5	1.5		2	1	0.6	0.4	
Tanaidae	1	1	0.2	0.1						
Unidentified isopods	54	12	2.7	11.4		19	4	2.4	2.1	
Amphipoda:										
Hyperiidae	4	2	0.5	2.0						
Gammaridae:										
Gammarus sp.	17	6	1.4	13.9		3	2	1.2	1.1	
Lysianissidae	519	10	2.3	167.6	0.4					
Phronimidae:										
Phronima sp.	170	62	14.1	43.6		3	3	1.8	1.0	
Unidentified Phronimidae	2	2	0.5	0.3						
Caprellidae:										
Caprella sp.	2	1	0.2	0.1						
Unidentified Caprellidae	2	2	0.5	1.0						
Unidentified amphipods	139	29	6.6	34.4		33	9	5.4	4.7	
Euphausiacea:										
Euphausiidae:										
Euphausia sp.	67	5	1.1	11.5		93	2	1.2	27.0	0.1
Unidentified euphausids	93	10	2.3	17.7		168	15	9.0	53.9	0.2
Decapoda:										
Penaeidae:										
Penaeus sp.	1	1	0.2	1.4		71	5	3.0	116.8	0.5
Unidentified Penaeidae	27	9	2.1	9.3		90	15	9.0	103.3	0.5
Palaemonidae:										
Palaemon sp.	9	7	1.6	11.5		19	8	4.8	34.2	0.2
Unidentified Palaemonidae	27	4	0.9	3.8		16	1	0.6	0.2	
Hippolytidae	1	1	0.2	7.5						
Nephropsidae:										
Enoplometopus sp.	7	3	0.7	2.5						
Unidentified Nephropsidae	2	1	0.2	0.5						
Palinuridae:										
Panulirus sp.	1	1	0.2	0.9						
Unidentified Palinuridae	1	1	0.2	0.8						
Megalopa larvae	212	31	7.1	42.0		1	1	0.6	0.1	
Phyllosoma larvae	2	2	0.5	0.2						
Unidentified decapods	48	10	2.3	36.4		47	4	2.4	38.5	0.2
Stomatopoda										
Squillidae:										
Squilla sp.	6	4	0.9	1.4						
S. alba	1	1	0.2	0.2						
Pseudosquilla sp.	2	2	0.5	0.9						
P. occulta	6	3	0.7	3.5						
Lysiosquilla sp.	7	4	0.9	3.7						
Coronida sp.	2	2	0.5	0.6						
Gonodactylus sp.	10	8	1.8	2.6						
G. guerini	32	7	1.6	7.3						
Odontodactylus sp.	1	1	0.2	0.6						
O. hensenii	18	7	1.6	6.7						
Unidentified stomatopods	2	2	0.5	0.3						
Unidentified crustaceans	4	3	0.7	0.8		1	1	0.6	1.0	
MOLLUSCA	[3,537]			[16,275.2]	[36.4]	[910]			[7,997.3]	[35.9]
Gastropoda										
Heteropoda										
Atlantidae	49	15	3.4	3.0		6	4	2.4	0.5	
Pterotracheidae:										
Pterotrachea sp.	1	1	0.2	0.3						
Unidentified heteropods	60	24	5.5	92.0	0.2					
Pteropoda										
Spiratellidae	2	2	0.5	0.7						
Unidentified pteropods	10	1	0.2	5.0						

See footnote at end of table.

TABLE 11.—*Check-list of food organisms found in the stomachs of 439 yellowfin and 166 bigeye tuna captured on longline in the Central Pacific, 1950–53*—Continued

[Family names of fishes are as given in Berg 1947]

Food organisms	Yellowfin					Bigeye				
	Number of organisms	Stomachs in which occurred		Aggregate total volume		Number of organisms	Stomachs in which occurred		Aggregate total volume	
		Number	Percent	Cubic centimeters	Percent[1]		Number	Percent	Cubic centimeters	Percent[1]
Cephalopoda										
Octopoda										
Octopodidae:										
Octopus sp.	2	1	0.2	20.0		2	1	0.6	7.7	
Unidentified Octopodidae	67	22	5.0	1,153.4	2.6	15	11	6.6	273.9	1.2
Argonautidae:										
Argonauta sp.	169	32	7.3	543.4	1.2	45	9	5.4	156.1	0.7
A. hians	72	8	1.8	273.2	0.6					
A. bottgeri	52	16	3.6	254.4	0.6	8	3	1.8	58.0	0.3
Unidentified argonauts	147	43	9.8	727.1	1.6	23	17	10.2	115.7	0.5
Bolitaenidae:										
Eledonnella sp.	2	2	0.5	45.0	0.1	2	1	0.6	20.0	
Unidentified octopods	7	7	1.6	35.2		4	4	2.4	29.4	0.2
Decapoda (squid)	[2,738]	[382]	[87.0]	[13,036.4]	[29.2]	[770]	[137]	[82.5]	[7,311.3]	[32.8]
Sepiidae:										
Sepia sp.						3	1	0.6	5.8	
Unidentified sepiidae	13	10	2.3	110.5	0.2	3	2	1.2	9.7	
Lolinginidae:										
Loligo sp.	2	1	0.2	3.8		10	3	1.8	62.8	0.3
Sepioteuthis sp.	22	12	2.7	382.3	0.9	26	7	4.2	1,080.0	4.8
Unidentified Loliginidae	333	59	13.4	2,205.0	4.9	85	24	14.5	1,252.8	5.6
Sepiolidae	7	5	1.1	277.8	0.6	9	5	3.0	334.0	1.5
Onycoteuthidae:										
Onycoteuthis sp.										
O. banksi						2	2	1.2	147.0	0.7
Teleoteuthis sp.	6	1	0.2	14.0						
Unidentified Onycoteuthidae	2	2	0.5	4.5		8	2	1.2	99.3	0.4
Histioteuthidae:										
Calliteuthis sp.	1	1	0.2	4.0						
Unidentified Histioteuthidae	10	5	1.1	14.2		6	3	1.8	34.0	0.2
Enoploteuthidae:										
Abralia sp.						8	2	1.2	41.0	0.2
A. astrosticta	4	1	0.2	14.2						
Enoploteuthis sp.	31	4	0.9	81.5	0.2	5	3	1.8	56.5	0.3
Unidentified Enoploteuthidae	162	67	15.3	397.4	0.9	77	35	21.1	414.8	1.9
Ommastrephidae:										
Notodarus sp.	40	9	2.1	179.9	0.4	2	1	0.6	120.0	0.5
Ommastrephes sp.	16	1	0.2	85.0	0.2					
Unidentified Ommastrephidae	923	175	39.9	3,534.6	7.9	205	42	25.3	2,482.0	11.1
Cranchiidae:										
Helicocranchia sp.	1	1	0.2	2.7		1	1	0.6	1.8	
Liocranchia sp.						95	4	2.4	131.0	0.6
L. globulus	61	7	1.6	116.1	0.3	74	3	1.8	207.8	0.9
Unidentified Cranchiidae	10	2	0.5	17.0						
Unidentified squid	1,094	143	32.6	5,591.9	12.5	151	48	28.9	830.9	3.7
Unidentified cephalopods	159	32	7.3	86.1	0.2	35	5	3.0	4.9	
CHORDATA										
Tunicata	[375]	[106]	[24.1]	[264.7]	[0.6]	[41]	[10]	[6.0]	[21.8]	
Thaliacea										
Salpidae:										
Salpa sp.	19	1	0.2	1.1						
Unidentified Salpidae	349	106	24.1	238.0	0.5	36	7	4.2	9.4	
Ascidiacea										
Pyrosomatidae	6	4	0.9	23.6		3	2	1.2	11.5	
Unidentified tunicates	1	1	0.2	2.0		2	2	1.2	0.9	
Vertebrata (Pisces)	[4,340]	[408]	[92.9]	[27,643.5]	[61.9]	[1,702]	[140]	[84.3]	[13,890.2]	[62.3]
Gonostomidae (viperfishes):										
Cyclothone sp.						2	1	0.6	2.0	
Vinciguerria lucetia	110	2	0.5	44.4		181	3	1.8	32.8	0.1
Unidentified Gonostomidae						1	1	0.6	2.1	
Sternoptychidae (hatchetfishes):										
Sternoptyx sp.	4	2	0.5	2.2		29	2	1.2	14.8	
S. diaphana	253	2	0.5	517.1	1.2	118	1	0.6	75.0	0.3
Argyropelecus sp.										
A. haemigymnus						4	1	0.6	14.3	
Unidentified Sternoptychidae	81	11	2.5	83.1	0.2	82	13	7.8	65.0	0.3
Stomiatidae	13	4	0.9	12.0		3	2	1.2	1.6	
Chauliodontidae						1	1	0.6	5.0	
Astronesthidae	1	1	0.2	0.2						
Melanostomiatidae	1	1	0.2	43.5						
Sudidae:										
Sudis sp.	1	1	0.2	3.6		4	2	1.2	76.1	0.3
Paralepis sp.						27	5	3.0	216.0	1.0
Lestidium sp.	1	1	0.2	2.5		24	2	1.2	123.0	0.6
L. nudum						6	1	0.6	17.5	
Unidentified Sudidae	47	28	6.4	197.9	0.4	44	18	10.8	214.8	1.0
Alepisauridae (lancet fishes):										
Alepisaurus sp.	41	16	3.6	172.3	0.4	36	17	10.2	635.4	2.8
Scopelidae (lantern fishes)	57	21	4.8	94.5	0.2	21	7	4.2	127.1	0.6
Muraenidae	6	1	0.2	1.4						

See footnote at end of table.

TABLE 11.—*Check-list of food organisms found in the stomachs of 439 yellowfin and 166 bigeye tuna captured on longline in the Central Pacific, 1950–53*—Continued

[Family names of fishes are as given in Berg 1947]

Food organisms	Yellowfin					Bigeye				
	Number of organisms	Stomachs in which occurred		Aggregate total volume		Number of organisms	Stomachs in which occurred		Aggregate total volume	
		Number	Percent	Cubic centimeters	Percent[1]		Number	Percent	Cubic centimeters	Percent[1]
Vertebrata—Continued										
Nemichthyidae (snipe eels)	3	1	0.2	3.4		1	1	0.6	0.5	
Belonidae (needle fishes)	13	6	1.4	10.7		7	6	3.6	12.0	
Hemirhamphidae (halfbeaks)	1	1	0.2	7.0						
Exocoetidae (flying fishes):										
Cypselurus sp	5	4	0.9	321.3	0.7					
Paraerocoetus sp	2	1	0.2	31.5						
Unidentified Exocoetidae	27	13	3.0	295.3	0.7	6	5	3.0	64.8	0.3
Bregmacerotidae:										
Bregmaceros macclellandi	4	3	0.7	6.6		1	1	0.6	1.0	
Gadidae (codfishes)	1	1	0.2	1.9						
Lophotidae (oarfishes)						1	1	0.6	2.8	
Trachypteridae (ribbon fishes):										
Trachypterus sp						2	1	0.6	40.0	0.2
Regalecidae (oarfishes):										
Regalecus sp						1	1	0.6	190.0	0.9
Berycidae	10	3	0.7	45.0	0.1	1	1	0.6	3.9	
Diretmidae	1	1	0.2	94.0	0.2					
Caulolepidae:										
Anoplogaster sp	5	2	0.5	21.6						
A. cornutus						9	2	1.2	21.0	
Unidentified Caulolepidae	27	3	0.7	94.0	0.2	1	1	0.6	6.4	
Holocentridae (squirrel fishes):										
Holocentrus sp	2	1	0.2	0.2						
Unidentified Holocentridae						1	1	0.6	0.1	
Zeidae (John Dories):										
Allocytus sp	2	2	0.5	5.3						
Caproidae:										
Antigonia sp										
A. capros						11	1	0.6	33.0	0.1
Atherinidae (silversides):										
A. insularum						150	1	0.6	55.4	0.2
Polynemidae (threadfins)	1	1	0.2	7.2						
Priacanthidae (catalufas):										
Pricanthus cruentatus	2	1	0.2	29.5						
Pseudopriacanthus sp						1	1	0.6	6.8	
Apogonidae (cardinal fishes):										
Parascombrops pellucida	1	1	0.2	0.6						
Scombropidae:										
Hypoclydonia sp	7	2	0.5	6.9		4	1	0.6	9.2	
Scombrops sp	8	2	0.5	4.6		1	1	0.6	1.9	
Unidentified Scombropidae						1	1	0.6	1.2	
Carangidae (jacks):										
Seriola sp	1	1	0.2	88.0	0.2					
Naucrates sp	1	1	0.2	118.0	0.3					
Carangus sp						1	1	0.6	8.6	
Scombroides sp	1	1	0.2	115.7	0.3					
Unidentified Carangidae	1	1	0.2	1.8						
Bramidae (pomfrets):										
Collybus drachme	1,012	190	43.3	3,465.9	7.8	76	26	15.7	2,550.8	11.4
Taractes sp	88	33	7.5	786.3	1.8	34	22	13.3	835.5	3.7
Pteraclis sp	1	1	0.2	3.0						
P. ocellatus	2	1	0.2	4.2		1	1	0.6	14.8	
Unidentified Bramidae	244	66	15.0	675.2	1.5	18	10	6.0	476.9	2.1
Coryphaenidae (dolphins):										
Coryphaenus sp	2	2	0.5	118.1	0.3					
C. hippurus	3	1	0.2	1.4						
Unidentified Coryphaenidae	2	2	0.5	3.3		3	2	1.2	2.6	
Lutianidae (snappers)	1	1	0.2	1.5						
Leiognathidae	8	1	0.2	21.0						
Mullidae (goat fishes):										
Pseudupeneus sp										
P. porphyreus	1	1	0.2	1.2						
Unidentified Mullidae						1	1	0.6	3.7	
Chaetodontidae (butterfly fishes)	5	3	0.7	29.3						
Pomacentridae (damsel fishes)	3	2	0.5	4.4		1	1	0.6	7.0	
Champsodontidae: *Champsodon* sp	26	10	2.3	39.5		1	1	0.6	2.0	
Chiasmodontidae	12	3	0.7	24.8		7	3	1.8	29.9	0.1
Acanthuridae (surgeon fishes):										
Hepatus sp	6	1	0.2	12.8						
Unidentified Acanthuridae	31	10	2.3	97.9	0.2					
Zanclidae (Moorish Idol)	1	1	0.2	21.9						
Gempylidae (snake mackerels):										
Gempylus serpens	202	80	18.1	2,119.5	4.7	86	43	25.9	2,023.7	9.1
Ruvettus sp	1	1	0.2	0.4		2	1	0.6	2.4	
Neolotus tripes	10	1	0.2	21.5		1	1	0.6	4.4	
Promethichthys prometheus	7	1	0.2	36.0						
Neoephinnula orientalis						1	1	0.6	5.5	
Rexea solandrii						2	1	0.6	2.8	
Mimasea taeniosoma	1	1	0.2	1.8		18	1	0.6	80.0	0.4
Unidentified Gempylidae	149	62	14.1	786.2	1.8	48	18	10.8	376.3	1.7

See footnote at end of table.

TABLE 11.—*Check-list of food organisms found in the stomachs of 439 yellowfin and 166 bigeye tuna captured on longline in the Central Pacific, 1950–53*—Continued

[Family names of fishes are as given in Berg 1947]

Food organisms	Yellowfin					Bigeye				
	Number of organisms	Stomachs in which occurred		Aggregate total volume		Number of organisms	Stomachs in which occurred		Aggregate total volume	
		Number	Percent	Cubic centimeters	Percent[1]		Number	Percent	Cubic centimeters	Percent[1]
Vertebrata—Continued										
Scombridae (mackerels):										
Scomber sp.	9	2	0.5	21.4						
Unidentified Scombridae	4	3	0.7	68.6	0.2					
Nomeidae (rudder fishes):										
Nomeus sp.	41	16	3.6	102.3	0.2	34	6	3.6	76.9	0.3
Cubiceps sp.	14	4	0.9	30.8		8	3	1.8	22.8	0.1
C. thompsoni	2	1	0.2	10.0						
Psenes sp.	41	12	2.7	79.0	0.2	4	2	1.2	10.4	
Monodactylus sp.						1	1	0.6	5.6	
Unidentified Nomeidae	58	25	5.7	122.6	0.3	15	10	6.0	75.0	0.3
Thunnidae (tuna fishes):										
Sardi sp.						3	1	0.6	17.5	
Katsuwonus pelamis	48	17	3.9	3,497.1	7.8					
Neothunnus macropterus	2	2	0.5	962.0	2.2	1	1	0.6	662.0	3.0
Germo alalunga	1	1	0.2	22.2						
Auxis thazard	68	12	2.7	1,964.0	4.4	2	2	1.2	224.0	1.0
Parathunnus sibi	1	1	0.2	70.0	0.2					
Unidentified Thunnidae	6	4	0.9	12.2		1	1	0.6	1.0	
Echeneidae (remoras):										
Echeneis sp.	16	8	1.8	144.8	0.3					
Remoropsis brachypterus	4	2	0.5	26.6						
Remora sp.	4	3	0.7	14.3						
R. remora	12	11	2.5	145.8	0.3					
Unidentified Echeneidae	26	20	4.6	116.3	0.3	7	3	1.8	5.6	
Balistidae (trigger fishes):										
Balistes sp.	8	5	1.1	72.6	0.2					
B. nycteris	23	12	2.7	412.5	0.9					
B. ringens	5	3	0.7	134.0	0.3					
Xanthichthys sp.	1	1	0.5	6.8						
Unidentified Balistidae	8	7	1.6	71.9	0.2					
Monacanthidae (file fishes)	11	7	1.6	27.8						
Ostraciidae (trunk fishes):										
Ostracion sp.	33	14	3.2	78.3	0.2	15	2	1.2	23.0	0.1
O. diaphanus	78	29	6.6	322.7	0.7	8	2	1.2	29.7	0.1
Lactoria sp.	3	3	0.7	15.3		1	1	0.6	2.5	
L. schlemmeri	18	13	3.0	243.4	0.5	2	2	1.2	69.5	0.3
Unidentified Ostraciidae	11	10	2.3	27.1		1	1	0.6	0.6	
Tetrodontidae (puffers):										
Sphoeroides lagocephalus	9	6	1.4	77.0	0.2					
Lagocephalus sp.	3	2	0.5	57.5	0.1					
Tetrodon sp.	3	2	0.5	215.7	0.5					
Unidentified Tetrodontidae	7	7	1.6	118.1	0.3	1	1	0.6	16.6	
Diodontidae (porcupine fishes):										
Diodon sp.	1	1	0.2	10.0						
Cheilomycteris sp.	5	5	1.1	66.1	0.1					
C. affinis	3	1	0.2	54.0	0.1					
Unidentified Diodontidae	13	10	2.3	162.3	0.4	1	1	0.6	0.1	
Molidae (sun fishes):										
Ranzania sp.	19	12	2.7	4,318.8	9.7	1	1	0.6	113.0	0.5
Unidentified Molidae						2	2	1.6	151.0	0.7
Antennariidae (frogfishes):										
Antennarius sp.	1	1	0.2	0.8						
Other and unidentified fish	1,160	213	48.5	2,968.9	6.6	511	81	48.8	3,884.0	17.4
Total food				44,679.5					22,297.3	
Number of stomachs examined				439					166	

[1] Given only when 0.1 percent or greater.

U. S. GOVERNMENT PRINTING OFFICE: 1956 O—388734

DISPLAY CO.

Reprinted from PACIFIC SCIENCE, *vol. X, no. 1, January, 1956*

Some Unusual Fishes From the Central Pacific

JOSEPH E. KING and ISAAC I. IKEHARA[1]

THE PURPOSE OF THIS ARTICLE is to call the attention of ichthyologists to certain rare or uncommon fishes recently collected in the central Pacific by staff members of the Pacific Oceanic Fishery Investigations at Honolulu, and others. These fishes have been deposited with the U. S. National Museum. The photographs included here were taken by E. D. Stroup; Figure 4 was prepared by Tamotsu Nakata.

SQUALIDAE

The first two species, here placed in the Squalidae following Hubbs and McHugh (1951), were formerly placed in the Dalatiidae, e.g. Bigelow and Schroeder (1948).

1. **Euprotomicrus bispinatus** (Quoy and Gaimard)

One female specimen (Fig. 1) (USNM No. 164176), 161 mm. in total length. Collected March 3, 1948, about 340 miles WNW of Johnston Island at 18°24′N., 175°12′W. in water about 1,000 fathoms deep. Attracted to a light and dip-netted at surface. Collected by M. B. Schaefer aboard M/V "Oregon" operated by Pacific Exploration Company.

Description: No anal fin; 2 dorsal fins without spines; snout blunt and broadly rounded; 5 gill openings, all anterior to pectorals; body nearly cylindrical; eyes lateral without nictitating membrane; a large spiracle present; mouth transverse with a groove extending posteriorly from each end; teeth with only 1 cusp and not serrated; upper teeth narrowly triangular and needle-pointed, lower teeth broader, compressed, and bent outwards; caudal axis scarcely upturned; no subterminal notch evident; end of base of first dorsal fin well in advance of the pelvic insertion; base of second dorsal fin very much longer than that of the first; denticles quadrate, with a central pit; first dorsal fin very much nearer pelvic base than pectoral base; body uniform brownish black (in alcohol after fixation in formalin), outer edges of fins clear. Measurements of the specimen and proportional measurements as per cent of total length are given in Table 1.

Hubbs and McHugh (1951) report the capture of a female *E. bispinatus*, 233 mm. total length, about 500 miles off the California coast. They give a thorough description of the specimen and state that it is ". . . the only extant example of the genus known from the Pacific Ocean and, so far as we know, the only one in an American museum." An earlier specimen collected in the open Pacific "between Honolulu and San Francisco, but nearer to the former" (Eigenmann, 1891) was destroyed in the San Francisco fire, according to Hubbs and McHugh. Since we can find no record of any capture of this species since

[1] Fishery Research Biologists, Pacific Oceanic Fishery Investigations, U. S. Fish and Wildlife Service, Honolulu, T. H. Manuscript received April 13, 1955.

TABLE 1

BODY MEASUREMENTS AND PROPORTIONAL MEASUREMENTS OF *Euprotomicrus bispinatus* AND *Isistius brasiliensis*
(Body Measurements in Millimeters, Proportional Measurements [bracketed] in Percentage of Total Length)

	*E. bispinatus**	*I. brasiliensis*†
Trunk at origin of pectoral: breadth	19.0 (11.8)	21.0 (11.1)
height	17.0 (10.6)	19.5 (10.3)
Snout length in front of: outer nostrils	3.0 (1.9)	1.5 (0.8)
mouth	17.0 (10.6)	13.0 (6.9)
Eye: horizontal diameter	6.0 (3.7)	8.0 (4.2)
Mouth: breadth	11.0 (6.8)	10.5 (5.6)
height	1.0 (0.6)	0.0 (0.0)
Nostrils: distance between inner ends	4.0 (2.5)	3.0 (1.6)
Labial furrow length from angle of upper jaw	8.0 (5.0)	11.0 (5.8)
Gill opening lengths: 1st	2.0 (1.2)	2.0 (1.1)
2nd	2.0 (1.2)	2.0 (1.1)
3rd	2.0 (1.2)	2.0 (1.1)
4th	1.5 (0.9)	1.5 (0.8)
5th	1.0 (0.6)	1.0 (0.5)
First dorsal fin: vertical height	2.5 (1.6)	4.0 (2.1)
length of base	2.5 (1.6)	6.0 (3.2)
Second dorsal fin: vertical height	3.3 (2.0)	4.0 (2.1)
length of base	14.0 (8.7)	7.0 (3.7)
Caudal fin: upper margin	25.0 (15.5)	27.0 (14.3)
lower anterior margin	20.0 (12.4)	20.0 (10.6)
Pectoral fin: outer margin	16.5 (10.2)	16.0 (8.5)
inner margin	10.5 (6.5)	11.0 (5.8)
distal margin	13.0 (8.1)	6.8 (3.6)
Distance from snout to: 1st dorsal	84.0 (52.2)	115.5 (61.1)
2nd dorsal	108.0 (67.1)	136.5 (72.2)
upper caudal	137.0 (85.1)	164.0 (86.8)
pectoral	40.0 (24.8)	42.0 (22.2)
ventrals	94.0 (58.4)	122.5 (64.8)
Interspace between: 1st and 2nd dorsals	21.0 (13.0)	16.7 (8.8)
2nd dorsal and caudal	16.0 (9.9)	20.5 (10.8)
Distance from origin to origin of: pectoral and ventrals	56.5 (35.1)	84.5 (44.7)
ventrals and caudal	41.0 (25.5)	41.0 (21.7)

* Female, 161 millimeters in total length.
† Female, 189 millimeters in total length.

1951, we believe that our specimen is the third example of the genus (monotypic) known from the Pacific and the second example in an American collection.

2. **Isistius brasiliensis** (Quoy and Gaimard)

One male specimen (USNM No. 164173), 165 mm. in total length. Collected March 2,

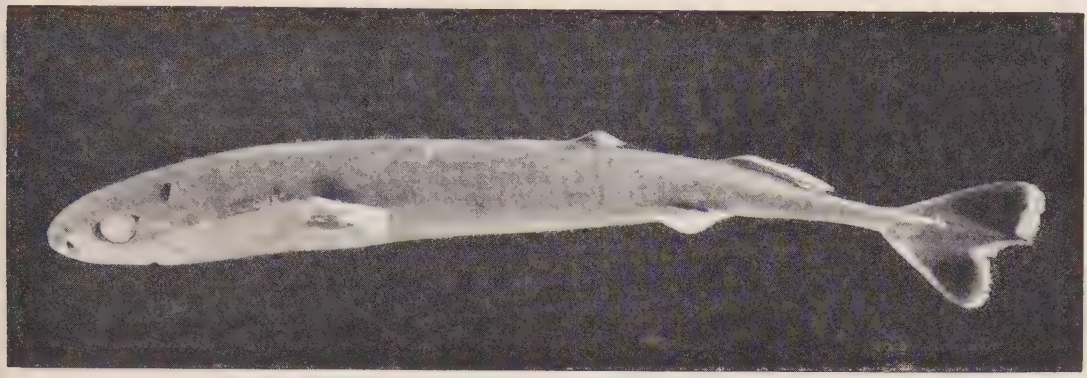


FIG. 1. Lateral view of a 161 millimeter (female) *Euprotomicrus bispinatus* captured at the surface with a dip net at 18°24′N., 175°12′W.

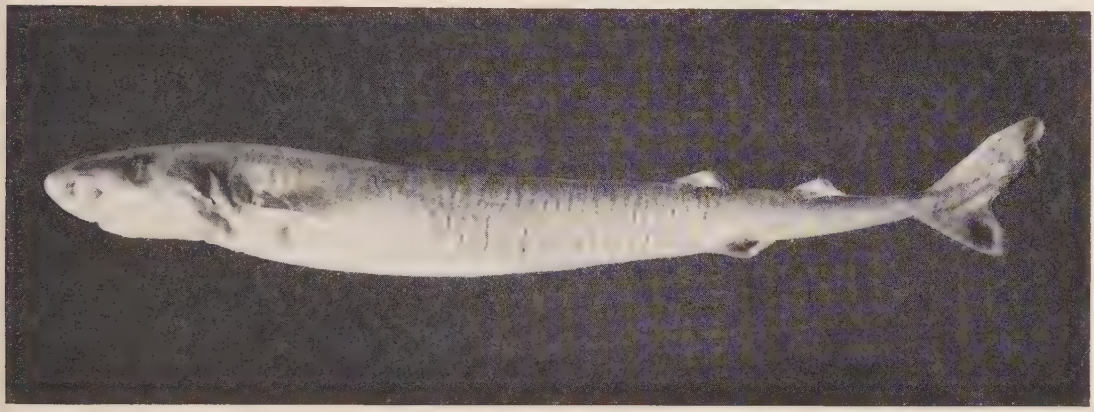


FIG. 2. Lateral view of a 189 millimeter (female) *Isistius brasiliensis* captured by pelagic trawl at 2°09′N., 158° 14′W.

1952, at about 11 P.M. aboard M/V "Hugh M. Smith" at 2°04′S., 168°57′W., in water about 3,000 fathoms deep. Collected by Heeny Yuen employing a 1-meter (mouth diameter) zooplankton net in an oblique haul to 200 meters depth.

A female specimen (USNM No. 164175), 179 mm. in total length. Collected May 23, 1954, at about 8:30 P.M. aboard M/V "John R. Manning" at 4°47′N., 161°04′W., in water about 2,000 fathoms deep. Collected by J. E. King and T. S. Hida in a 6-foot Isaacs-Kidd trawl; depth of haul about 100 meters.

A second female (Fig. 2) (USNM No. 164174), 189 mm. in total length. Collected June 2, 1954, at about 8:30 P.M., aboard M/V "John R. Manning" at 2°09′N., 158°14′W., in water about 1,000 fathoms deep. Collected by J. E. King and T. S. Hida in a 6-foot Isaacs-Kidd trawl with depth of haul about 100 meters. Measurements of this specimen are given in Table 1.

Description: No anal fin; 2 dorsal fins, without spines; snout blunt and broadly rounded; 5 gill openings, all anterior to pectorals; body nearly cylindrical; eyes lateral, without nictitating membrane; a large spiracle present; teeth with only 1 cusp and faint indications of serration; teeth of the upper and lower jaw very unlike, the upper are slender and curved

outwards while the lower are much larger and erect, with subquadrate bases and triangular sharp-pointed cusp; caudal axis scarcely upturned; subterminal notch in caudal fin slight; mouth transverse, with fleshy lips and a groove extending backwards and outwards from each end; unlike *E. bispinatus*, the first dorsal fin is displaced backward so that the end of its base is over the origin of the pelvic base; dorsal fin bases nearly equal; denticles quadrate with a median pit; first dorsal fin very much nearer pelvics than pectoral base; body dark brown above (in alcohol after fixation in formalin), pale grayish brown below except for a dark collar across the throat; fins with outer edges clear except the upper lobe of the caudal, which is brown to the margin.

This small oceanic shark, although uncommon, is not nearly as rare as *E. bispinatus*. According to Bigelow and Schroeder (1948), *I. brasiliensis* is distributed throughout the tropical and subtropical belts of all three oceans; however, records of its occurrence in the eastern and central Pacific are few. One specimen was taken by the "Albatross" (Garman 1899) at 2°34′N., 92°06′W. F. D. Bennett (1840) captured two specimens, which he classified as *Squalus fulgens*, in a net towed at the surface; one of these, 10 inches in length, he reported as taken at 2°30′S., 163° W., and the other, 18 inches in length, at 55°N., 110°W. Garman (1899) pointed out the obvious error in the latter position and stated that the actual longitude was 140°W. Later G. Bennett (1860) collected a 5.5-inch specimen, which he classified as *Scymmus* sp., at 2°15′S., 163°W. Jordan and Jordan (1922) report the occurrence of this small shark in Hawaiian waters under the name *Apristurus spongiceps* (Gilbert). Fowler and Ball (1925) state that a specimen classified earlier (Fowler 1923) as *Echinorhinus brucus* (Bonnaterre) in Bernice P. Bishop Museum collections from Hawaiian waters is actually *I. brasiliensis*. All the above names are placed in synonymy with *I. brasiliensis* by Bigelow and Schroeder (1948).

The Bennetts' description of the luminiscence of this fish has been quoted often. This characteristic was not observed in our three specimens, possibly because all three were dead when brought on deck. The luminiscence is reported to fade out as the fish dies.

LOPHOTIDAE

3. **Eumecichthys fiski** (Günther) Regan

One specimen (Figs. 3 and 4) (USNM No. 164170), 598 mm. in standard length. Collected June 1, 1954, at about 12:15 P.M. aboard M/V "John R. Manning" at 3°04′N., 159°13′W., in water about 900 fathoms deep. Dip-netted at the surface by Howard Kamauu, fisherman on the "Manning."

Description: Body elongate, strongly compressed, nearly of uniform depth throughout, scaleless, snout prolonged as a sword-shaped process bearing near its tip a pronounced plume or crest (Fig. 3); dorsal fin commences at the tip of this process with an extremely long and compressed ray, then continues to the caudal averaging in height about one-fourth the body depth; both jaws are armed with small, hooked teeth; premaxillary nonprotractile; eye large; no ventral fins; anal fin rudimentary, base about 3 mm., height less than 1 mm. (Fig. 4); body silvery (in alcohol after fixation in formalin) with about 30 dark bars or blotches, most prominent dorsally; occipital crest and dorsal and caudal fins were crimson in life but faded completely in formalin.

Fin ray count: D. 326; P. 13(R), 12(L); C. 10.

Body measurements (in millimeters) and proportional measurements (bracketed) as percentage of standard length: snout to vent, 579.0 (96.7); vent to base of caudal, 20.5 (3.4); caudal fin length, 25.5 (4.3); head length including snout, 64.0 (10.7); snout length in front of mouth, 30.0 (5.0); snout to origin of pectoral, 64.0 (10.7); greatest body height, 21.3 (3.6); greatest body breadth, 7.0 (1.2); pectoral fin length, 13.0 (2.2); pectoral fin base, 5.0 (0.8); dorsal fin height at mid-point of body, 6.0 (1.0); dorsal fin

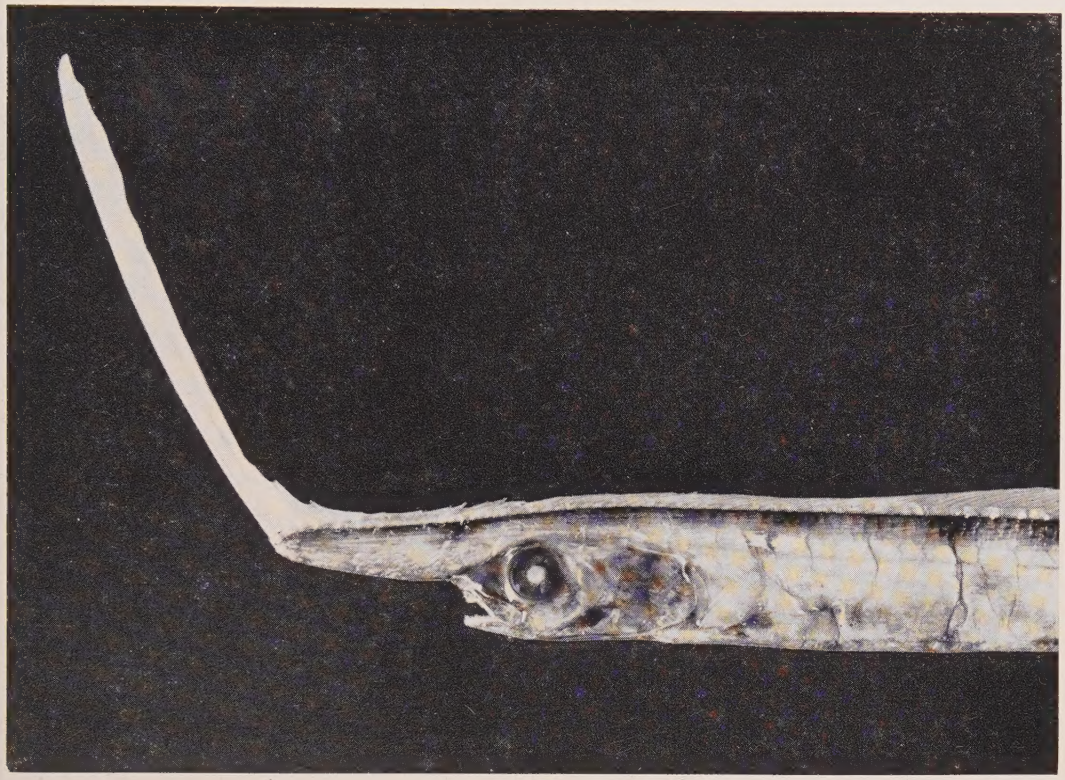


FIG. 3. Head portion of a 625 millimeter specimen of *Eumecichthys fiski* captured at the surface in a dip net at 3°04'N., 159°13'W.

height at origin of pectoral, 4.0 (0.7); dorsal fin height above vent, 5.0 (0.8); crest height, 83.0 (13.9); eye diameter, 8.0 (1.3).

Details of the capture of this rare fish are perhaps of interest. About midday shortly after starting to haul longline, we (J. E. King and T. S. Hida) noticed a thin "shadow" near the surface just to the rear of the point where the line was emerging from the water. When we finally decided that this was not just the wake or the shadow of the line but an unusual object in the water, a dip net was hastily obtained and this very rare fish was scooped from the water. After it had lain on a canvas hatch cover for a few minutes, we noticed that a black fluid had been discharged from the vent. Kershaw (1909) and Griffin (1934) have reported that lophotid fishes may emit an inky fluid from the vent when captured.

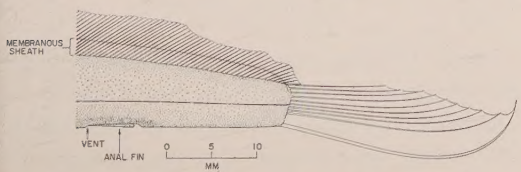


FIG. 4. Tail portion of *Eumecichthys fiski*, same specimen as in Figure 3, with the caudal fin expanded to show the detailed structure of the fin.

Eumecichthys fiski was described by Günther (1890) as *Lophotes fiski* from a 50-inch specimen that washed up on the shore of Kalk Bay (Atlantic Ocean), South Africa. In this fish the caudal region was mutilated so that Günther did not know the nature of the caudal fin nor whether or not an anal fin was normally present. Apparently no additional examples had appeared in South Africa by the time of the recent revision of "The Sea Fishes

of South Africa" by Smith (1953). From our examination of available literature, we conclude that all subsequent collections of *E. fiski*, except for our specimen from the central Pacific, have been from Japanese waters. Kamohara (1949) states that "In Japan a specimen 88.1 cm. in length was collected off Kōchi in 1939 by a worker from the Kōchi Prefectural Fisheries Experiment Station and was reported by Dr. Kiyomatsu Matsubara. This was the first record from Japan. Thereafter it transpired that several specimens had been captured in 1937 off Hagi in Yamaguchi Prefecture, and that it had also been collected earlier in Wakayama Prefecture." [Translated from the Japanese by W. G. Van Campen.] There is no reference to this species in *The Fishes of Oceania* (Fowler, 1928) and its supplements, or in *The Fishes of the Indo-Australian Archipelago*, Vol. V (Weber and De Beaufort, 1929), which includes the Allotriognathi.

TRACHYPTERIDAE

4. ? **Trachypterus iris** (Walbaum)

Two specimens (USNM No. 164172), both juveniles; one 84 mm. in standard length (caudal fin broken), the other 109 mm. in standard length (146 mm. total length with caudal depressed to the horizontal). Collected May 4, 1953, at about 8 P.M. aboard M/V "John R. Manning" at 8°32′N., 150°12′W., in water about 2,700 fathoms deep. Collected by W. F. Royce and W. M. Matsumoto in a 10-foot Isaacs-Kidd trawl; depth of haul about 200 meters.

Description: Body elongate, strongly compressed, scaleless; dorsal fin extends length of body; caudal fin divided, the larger portion pointing upwards; rays of dorsal bear numerous spinules; lateral line spinous; vent located on mid-ventral line in contrast to the following species; anterior profile steep, almost vertical; mouth protractile; body pale colorless (in alcohol after fixation in formalin).

Fin ray count: D. 160 ± 2; P. (broken); V. 5; C. 7 (upper), 5 (lower).

Body measurements (in millimeters) and proportional measurements (bracketed) as percentage of standard length (109 mm.): snout to vent, 70.0 (64.2); vent to base of caudal, 42.0 (38.5); caudal fin length, 34.0 (31.2); greatest body height, 18.0 (16.5); greatest body breadth, 6.0 (5.5).

5. ? **Trachypterus woodi** Smith

One specimen (Fig. 5) (USNM No. 164 171), a juvenile, 113 mm. standard length (125 mm. in total length with caudal depressed to the horizontal). Collected May 25, 1954, at about 8:30 P.M. aboard M/V "John R. Manning" at 4°41′N., 159°53′W., in water about 2,000 fathoms deep. Collected by J. E. King and T. S. Hida in a 6-foot Isaacs-Kidd trawl; depth of haul about 100 meters.

Description: Body strongly compressed; dorsal fin extends length of body; rays of dorsal with numerous spinules, each ray with a pair of larger spines near its base; rays at anterior end of dorsal show evidence of having been prolonged but are now broken; anterior profile steep but less than vertical; body covered with small, smooth tubercles, particularly prominent in the ventral region; lateral line spinous; no anal fin; caudal fin turned upwards, with no downward projecting portion as in previous specimen; vent located on left side of body about 2 mm. above mid-ventral line (the asymmetrical location of vent in *T. misakiensis* was pointed out by Herre and Herald in 1950); body silvery (in alcohol after fixation in formalin) with scattered dark blotches below dorsal and perhaps seven small blotches extending posteriorly in a line beginning at the upper margin of the eye; fins pink in life, clear in alcohol.

Fin ray count: D. 144, P. 12, V. 9, C. 8.

Body measurements (in millimeters) and proportional measurements (bracketed) as percentage of standard length: snout to vent, 78.5 (69.5); vent to base of caudal, 34.0 (30.0); caudal length, 12.5 (11.0); head length, 22.0 (19.4); eye diameter, 7.3 (6.4); snout to origin pectorals, 19.0 (16.7); snout to origin ven-

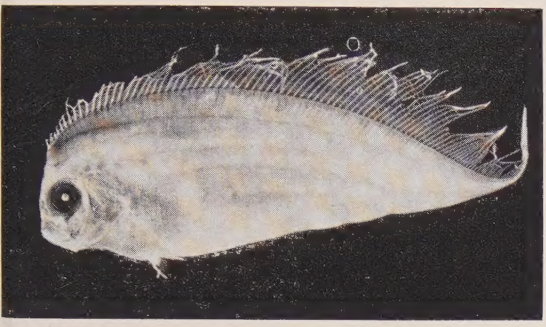


FIG. 5. Lateral view of *?Trachypterus woodi* Smith captured by pelagic trawl at 4°41'N., 159°53'W.

trals, 23.0 (20.3); greatest body height, 38.0 (33.5); greatest body breadth, 8.0 (7.0); greatest height of dorsal fin, 18.0 (15.9).

Most of the trachypterids examined by ichthyologists have been washed up on shore and usually were in poor condition; our specimens are among the few to be collected in nets, and one of the three, at least, is in excellent condition. These fishes are noted for their change in body proportions during development after the postlarval period (Hubbs, 1926). The juveniles are particularly difficult to identify. On the basis of available literature we have decided that two of our specimens are most likely *T. iris* (Walbaum), which is principally a Mediterranean species, whereas the third resembles *T. woodi* Smith. Although the identification is not certain due to limited library facilities and lack of sufficient reference material, our description, measurements, and the accompanying figure may provide some worthwhile information to those who are interested in the life history of these unusual fishes.

REFERENCES

BENNETT, F. D. 1840. *Narrative of a whaling voyage round the globe, from the year 1833 to 1836.* Vol. 2. vii + 395 pp. Richard Bentley, London.

BENNETT, G. 1860. *Gatherings of a naturalist in Australasia.* xii + 456 pp. John Van Voorst, London.

BIGELOW, H. B., and W. C. SCHROEDER. 1948. Sharks. In: Fishes of the western North Atlantic. Part I. *Sears Found. Mar. Res., Mem.* 1: 59–576.

EIGENMANN, ROSA S. 1891. Description of a new species of *Euprotomicrus. Calif. Acad. Sci., Proc.* II, 3 (1): 35.

FOWLER, H. W. 1923. New or little-known Hawaiian fishes. *Bernice P. Bishop Mus., Occas. Papers* 8 (7): 375–392.

——— 1928. The fishes of Oceania. *Bernice P. Bishop Mus., Mem.* 10: 1–540.

FOWLER, H. W., and S. C. BALL. 1925. Fishes of Hawaii, Johnston Island, and Wake Island. *Bernice P. Bishop Mus., Bul.* 26: 1–31.

GARMAN, S. 1899. Reports on an exploration off the west coasts of Mexico, Central and South America, and off the Galapagos Islands, in charge of Alexander Agassiz, by the U. S. Fish Commission steamer "Albatross" during 1891, Lt. Commander Z. L. Tanner, U. S. N., commanding. XXVI. The fishes. *Harvard Univ., Mus. Compar. Zool., Mem.* 24: 1–431.

GRIFFIN, L. T. 1934. Description of a rare lophotid fish from Cape Runaway, New Zealand. *Auckland Inst. and Mus., Rec.* 1 (5): 239–243.

GÜNTHER, A. C. L. 1890. Description of a new species of deep-sea fish from the Cape (*Lophotes fiski*). *Zool. Soc. London, Proc.* 1890: 244–247.

HERRE, A. W., and E. S. HERALD. 1950. Noteworthy additions to the Philippine fish fauna with descriptions of a new genus and species. *Philippine Jour. Sci.* 79 (3): 309–340.

HUBBS, C. L. 1926. The metamorphosis of the California ribbon fish, *Trachypterus rex-salmonorum. Mich. Acad. Sci., Arts, and Letters, Papers* 5 (1925): 469–476.

HUBBS, C. L., and J. L. MCHUGH. 1951. Relationships of the pelagic shark *Euprotomicrus bispinatus*, with description of a specimen from off California. *Calif. Acad. Sci., Proc.* IV, 27 (6): 159–173.

JORDAN, D. S., and E. K. JORDAN. 1922. A list of the fishes of Hawaii, with notes and descriptions of new species. *Carnegie Mus., Mem.* 10 (1): 1–92.

KAMOHARA, T. 1949. *Deep-sea fishes.* 203 pp. Nippon Shuppansha, Osaka. [Translated in part by W. G. Van Campen.]

KERSHAW, J. A. 1909. Additions to the fish fauna of Victoria. No. 2. *Victorian Nat.* 26: 78–79. [Not seen.]

REGAN, C. T. 1907. On the anatomy, classification, and systematic position of the teleostean fishes of the sub-order Allotriognathi. *Zool. Soc. London, Proc.* 2: 634–643.

SMITH, J. L. B. 1953. *The sea fishes of southern Africa.* xvi + 564 pp. Central News Agency, Ltd., Cape Town.

WEBER, M., and L. F. DEBEAUFORT. 1929. *The fishes of the Indo-Australian Archipelago.* Vol. 5. xiv + 458 pp. E. J. Brill, Leiden.